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Vol. 31 May, 1939 No. 5

Installation of a 54-inch Steel Intake Line

By E. P. Stewart

THE city of Syracuse takes its water supply from Skaneateles Lake, a Finger Lake located 19 miles southwest of the city. It is a gravity supply.

When this supply was first developed in 1893 to 1894, a 54-inch steel intake pipe, approximately 6,400 feet long was laid in the lake south from Skaneateles, the village at the northern end of the lake,

For a few years prior to 1930, the consumption of the city had increased to such an extent that the maximum capacity of the intake was required during hot, dry weather in the summer months. At such times, the loss in the intake amounted to as much as nine feet of head. This produced a dangerous condition in the land section of the intake pipe where the cover is as much as 19 feet. We felt some concern that, with low internal pressure, pipe of this age might collapse under such a heavy earth load.

While inspections by divers indicated that the pipe was in excellent condition, we felt that the time had come when a second intake should be constructed to serve both as an alternate supply line and to provide greater capacity.

The capacity of the conduit system to the city exceeded that of the intake and was entirely in duplicate and mostly in triplicate.

A paper presented at the New York Section meeting at Rochester, New York, March 30, 1939, by E. P. Stewart, Division Engineer, Water Supply Division, Syracuse, N. Y.

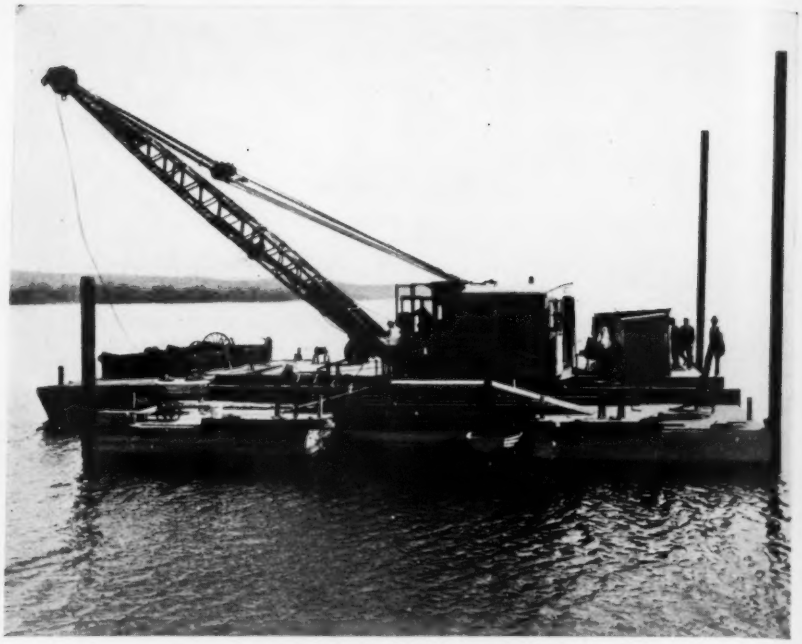

FIG. 1. Shovel Mounted Between Two Scows

FIG. 2. Note the Dropped Section on Which the Shovel Rests. The work at hand is raising the launch which ran upon a pile one dark night and sank.

The land section of the new intake was constructed in 1931. This portion was installed prior to the main project on account of the repaving of Route 20 through the village of Skaneateles. Our intakes pass from the gate house under this roadway and through a village park, to a seawall at the lake shore, a distance of approximately 200 feet. While it was planned at the time to continue with the lake section of the intake, financial conditions and a sharp reduction in consumption, due to the depression, delayed our program. Early in 1938, however, funds being available for the work and the consumption again on the increase, it was decided to construct the lake section during the summer season of that year.

If Skaneateles Lake had a navigable outlet, we probably would have let a contract for this work to some concern well equipped with dredges, tugs and other marine equipment. However, as boats of suitable size would have to be constucted or assembled on the lake shore by anyone doing this work, and as the Water Division has done its own construction work for many years, we decided to build our own boats, use as much of our own equipment as possible, and do all of the work with our own forces.

In 1931, we built and launched two flat scows 65 ft. long, 16 ft. wide, and 4 ft. in depth, and a two-compartment mud scow 50 ft. long, 14 ft. wide and 4 ft. deep.

As the Water Division owned a one and one-quarter yard Browning Gas Shovel, equipped with both crane boom and back hoe, it was decided to mount this piece of equipment on the two large scows and use this unit for excavation and back-filling.

We gave considerable study to methods of mounting this 40-ton unit on the wooden scows. The scheme which appealed most to us, and the one which was finally adopted, was to separate the two scows 16 ft. apart and to mount the shovel on steel I-beams supported from the decks. It would have been simple if we could have set the bottom of the caterpillar treads above the level of the deck, but as most of our trench sub-grade was 19 ft. below the level of the lake, our excavation efficiency would be greatly improved by supporting the shovel between the scows just above the surface of the water. This procedure necessitated the use of two steel hangers 48 ft. long with dropped sections or offsets between the scows. Twenty-one-inch I-beams were used between the scows and 18-inch I-beams across the decks. Channels were provided at the outer ends of these hangers extending down below the bottom of the scows. Running between these hangers and across the bottoms of the scows were tie rods with turn buckles. (See figs. 1 and 2.)

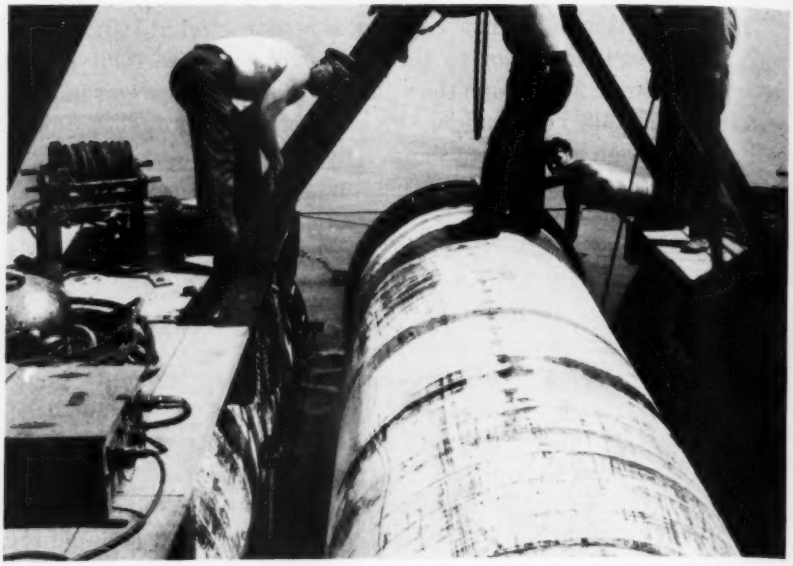

FIG. 3. The Catamaran Used to Lower 90-foot Lengths of Line

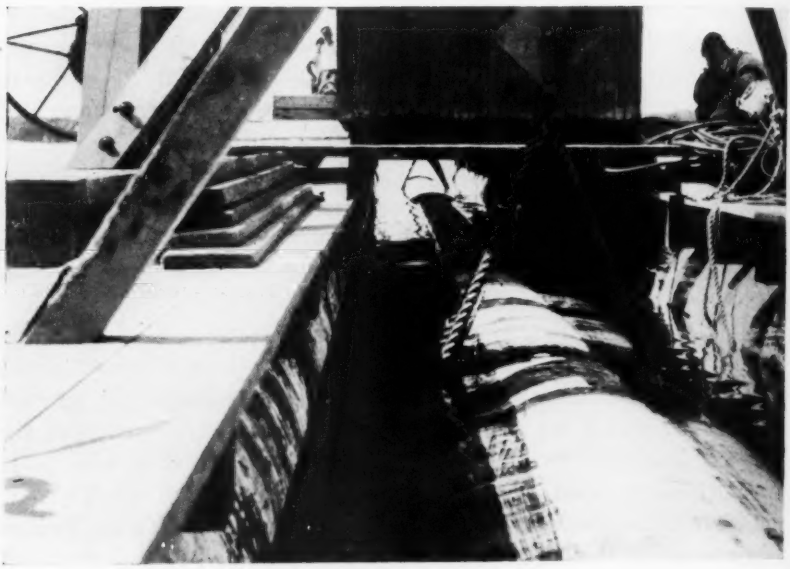

FIG. 4. The Pipe Is Being Lowered from the Catamaran

Not the least of our worries on this job was the loading of the shovel onto the hangers between the scows. This was accomplished without mishap, however, a great deal of care having been taken in the preparation of the loading ramp.

This somewhat unusual vessel was then equipped with a shelter house on deck, self-priming gasoline pump, anchors, winches, life preservers, toilet facilities and other miscellaneous equipment; and was ready for the season's work.

One feature of the design of our excavating unit gave us considerable concern, especially when the lake was rough. With a quartering wind, it was noticed that the scows did not ride the waves in unison, thereby introducing undesirable strains in the steel hangers. Too much of this strain might loosen joints or crystallize steel with disastrous results. We finally conceived the idea of providing an outrigger across the bows of the scows, made of steel beams, and this satisfactorily solved the "pumping" action.

While the Water Division already owned one 48-foot and one 28-foot motor boat, we needed a boat of tug design for towing the heavy excavating unit and the mud scow. There was no equipment of this type available on the lake, so we inquired at the lake ports on Lake Erie and Lake Ontario for a tug heavy enough to do this work and yet not so large but that it could be transported by trailer to Skaneateles Lake. We were fortunate in finding a 36-foot wooden boat having the required qualifications at Grand Island in the Niagara River. This boat had a heavy duty slow speed engine of about 100 h.p.

As the excavating unit would be required throughout the season for trenching, we needed some equipment for laying our pipe. After some study it was decided to use bulkheaded sections of the intake pipe itself as pontoons, and to construct therewith a catamaran from which the pipe could be laid. Such a catamaran was constructed, 90 ft. in length, with a space between the 54-inch pipe sections of about 6 ft. The pipe sections were held in place by means of saddles and straps attached to cross timbers. These timbers were decked over except at the ends where wooden "A" frames were erected, from which the pipe was supported and lowered by means of wire cables and blocks and hand-operated winches. The catamaran was equipped also with shelter houses for the divers and the pipe laying crew, life preservers, fire extinguishers and toilet facilities. (See figs. 3 and 4.)

A 28-foot motor boat, which was partly enclosed, was used as a service boat on the project. As this craft was used by the night watchmen, it was on 24-hour duty throughout most of the season.

Steel, concrete and gunite were considered as materials for the lake section of this intake, but steel was finally selected as being best adapted and most economical for this installation. Fifty-five inch outside diameter arc-welded steel pipe was used, with a wall thickness of $\frac{7}{16}$ in. It was furnished in 30-foot lengths by the Bethlehem

FIG. 5. Truck and Trailer Used to Haul the Pipe

Steel Company from their Leetsdale plant. It is coated inside and out with bitumastic material, the lining being spun in place to an average thickness of $\frac{3}{32}$ in. The coating was applied mechanically while the pipe was rotated.

We removed the pipe from flat cars in the village of Skaneateles by means of a hand-powered stiff leg derrick. One length at a time was then placed on a large motor truck and two-wheel trailer as shown in fig. 5. Using this method, the pipe was transported about two miles to a pipe yard on the east shore of the lake. It was unloaded down a ramp onto skids, on which it was rolled down a gentle slope to the shore line (fig. 6). There three 30-foot lengths were joined together with Dresser couplings, forming a 90-foot section (fig. 7). This

FIG. 6. Lowering a Length of Pipe to the Skids

FIG. 7. Three 30-foot Lengths Are Joined Together. (Photographed by Gene Logan)

section was bulkheaded on each end with steel caps which were joined to the pipe section by means of Dresser couplings (see figs. 8 and 9). The section was lowered down skids into the lake and towed by the tug to the catamaran as shown in fig. 10.

The deck of the catamaran was high enough to allow a 90-foot section of pipe to be floated into place under the deck between the pipe pontoons described above. Two 2-inch rope slings were placed around the end pipes in this 90-foot section and attached to the cable falls. Water was then admitted into the pipe section through 6-inch valves at the bottom of the bulkheads. The air escaped through 2-inch valves at the top of the bulkheads. The weight of the pipe section was then fully supported by the two cable falls. The total weight of the section and bulkheads was about 14 tons. The section was then lowered to the lake bottom by means of the hand winches. The winches were originally equipped with hand cranks, but as these were found to be dangerous and difficult to use, they were replaced with 48-inch hand wheels which furnished a perfect means of controlling the descent of the pipe section.

Bulkheads Removed by Divers

After the pipe had been lowered, two divers descended and removed the bulkheads which were hoisted to the surface to be used again on succeeding pipe sections.

The pipe was laid on crushed stone piers surmounted by wooden blocks loaded with concrete. These supports were provided at 15-foot intervals, and were designed to support the pipe approximately one foot above sub-grade. The amount of stone in each pier varied considerably due to unevenness of the lake and trench bottoms.

The stone was delivered at the pipe yard and transported to the catamaran in metal ash buckets by the motor boat. It was dumped in place from the catamaran and adjusted to the proper grade by the divers. The approximate quantity of stone required was placed from the deck of the catamaran before the 90-foot pipe section was in position. Additional stone required to bring the pipe to the proper grade was dumped as near the side of the pipe as possible and pushed under the pipe by the divers. The divers also placed and bolted up the Dresser couplings when the pipe had been brought to the proper line and grade.

The usual method of holding dredges in position while excavating is by the use of spuds. However, in this particular case, and with our equipment, we believed that the most economical and practical

FIG. 8

FIG. 9

FIG. 8. Installing the Bulkhead
FIG. 9. Bulkhead in Place with the Water Intake and Air Outlet Valves

FIG. 10. The Tug Hauls the 90-foot Length to the Catamaran
(Photographed by Gene Logan)

means of holding the excavator and catamaran in position was to drive piles at suitable intervals throughout the length of the project. This plan was perfectly feasible as the water depth varied from a few feet at the seawall to 21 ft. at the end of the line, and as the lake bottom material for the most part is clay.

Before deciding on the spacing of the piles, we built a model of our excavating unit to scale, and experimented with pile spacing which would provide a minimum amount of sway of the equipment when attached to the piles with cables, and yet be spaced far enough apart to make the plan economically practical. Our studies indicated that two lines of piles spaced 50 feet each side of the pipe line, and a pile spacing of 150-foot intervals would be satisfactory. This spacing was adopted.

The gas shovel, equipped with the crane boom and a set of leads, was used as a pile driver to drive the piles.

Equipment Moved by Hand Winches

Both the excavating unit and the catamaran were equipped with four hand winches, each of which carried about 200 ft. of cable. These cables were attached to the piles from the bow and stern of each unit. This was found to be a most satisfactory method of holding the equipment steadily on line, and also provided a ready means of moving the equipment along the line of excavation or pipe line by taking up and paying off on the fore and aft winches. Periodically, as needed, the cables were changed to a set of piles ahead. The tug was used for this work.

The piles proved to be very successful in many ways. For instance, they were used as offset stakes to the line of pipe, the offset of each pile from the center line of the intake having been previously determined from the shore by means of a transit. They also provided adequate means of mooring all of the equipment when work was not in progress.

As there is no shelter available at the north end of the lake during storms from the south, we were obliged to keep the excavating unit and the catamaran on line at all times. While Skaneateles is a relatively small lake, a high south wind produces a sea against which it would have been very difficult to have held our equipment by means of spuds or anchors.

At the completion of the work, some of the piles were removed by pulling and others by cutting off at the lake bottom.

Work was first begun on the intake at the outer end, where a small circular area was excavated to a depth of 3 ft., in which a 60-inch steel cross was placed which provided three inlets to the intake pipe. This cross was mounted on a 3-foot pedestal of crushed stone. From here to a point about 2,700 ft. out from the seawall, the pipe was laid approximately one foot above the lake bottom. From this location to the seawall, however, it was necessary to excavate a trench varying in depth from 0 to 13 feet. This was done for the most part with a one and one-quarter yard drag line bucket. The width of the trench averaged about 11 ft. Part of the excavated material was dumped in the mud scow while it was available, and the balance along the side of the trench. When full, the mud scow was towed out over the line of the pipe already laid, and the material in the two compartments dumped simultaneously on each side of the pipe. Where the pipe lay on open lake bottom, this backfill supported it against any side thrust; and where located in the trench, the material so deposited formed a partial backfill. When all of the pipe had been laid, the trench was completely backfilled for several hundred feet out from the seawall, but the only additional backfilling done was in locations where it was necessary to remove any spoil piles which might be a menace to navigation of boats.

Hard Clay Prevented Trench Cave-ins

Most of the material excavated was hard impervious clay. This material was difficult to excavate with a drag line bucket, but was much more so with our clam shell bucket. However, this hard material had the advantage of providing a trench with firm sides which did not slump. Near the shore some softer material was encountered, and considerable time was lost in re-excavating portions of the trench which caved in before the pipe could be laid.

Pile driving, the first operation on the lake, began on April 25, 1938, and was completed in nine days; 59 piles having been driven. Excavation was begun immediately, and was completed by September 28, 1938. While no accurate measurements of the excavation were made, the yardage moved is estimated at 7,200 cu.yd. The first pipe was laid on May 21, 1938, and the closing length at the seawall was connected up on October 3, 1938. Laying was discontinued for 15 days when the laying crew overtook the excavator. In all, 139 thirty-foot lengths, one 15-foot length, two 60-inch to

54-inch reducers, and the 60-inch cross were laid, making a total length of 4,210 feet.

The total cost of the lake section of the intake was about $121,000, making a unit price of $28.71 per ft. This included all preparation and equipment costs.

Perhaps one of the most interesting features of this installation was the fact that out of 20 men employed on this work, all except four were regularly employed by the City on construction and maintenance work. Of these, the general foreman and one of his assistants, the shovel operator and one of the diver's tenders were the only men who had had any marine construction experience.

One of the two divers, who is one of our best pipe men, was trained entirely on this job. One professional diver with much experience and two tug operators were hired especially for this project.

Most of our own men at the beginning of the job did not know a deck from a hatch or the bow from the stern of a boat. They made up this deficiency, however, by willingness and hard work.

Fish Catastrophes During Droughts

By George G. Schaut

TWICE during the writer's experience as chief chemist of the Bureau of Water of Philadelphia, mass destruction of fish life in the Schuylkill River has been observed. On neither occasion was the cause detectable by surveys of the river or by the ordinary sanitary analyses of its water. This work was primarily conducted to develop some data relative to the phenomenon.

The effluents of most industrial plants are usually complex liquids. The knowledge of the effect of pure chemicals upon fish life is sometimes helpful in pollution investigations. For this reason studies were made on five general classes of possible poisonous materials: 1. chemical salts and liquids, 2. gases, 3. industrial wastes, 4. nitrogenous products of an organic nature, 5. natural occurring plant principles.

In this report only a few references to the literature will be found. This is not due to the fact that the writer has not kept in close contact with the work of others, but because it does not appear useful to take up space by repetition of something that has so admirably been compiled by Ellis (1) in his recent work on stream pollution. This report is a document which no one interested in this field of research should fail to read.

Before conducting these experiments the question of time of contact of the fish with the material under test was given serious thought. One can readily appreciate that short time of contact might not be a fair method of evaluation of the toxicity of the material to fish. The time used by the Standing Committee on Rivers Pollution of the Ministry of Agriculture and Fisheries (2) in England was one to three hours where the experimenters were not trying to determine

A contributed record of research from the Laboratories of the Bureau of Water of the city of Philadelphia. Research directed and record produced by George G. Schaut, Chief Chemist, Bureau of Water, Philadelphia.

death point concentrations. As a matter of fact they state "as a datum for an opinion with regard to the toxicity of a given effluent, it has been assumed that should no physiological abnormality be observed in yearling perch or trout during treatment extending over one to three hours, such effluent will most probably not be immediately and directly harmful to the inhabitants of a stream" and "while not immediately and directly harmful is prejudicial when exposure is prolonged over considerable periods of time, either by their effects upon the tissues of the fish or upon the balance of life in the water."

The English authorities noted the time and nature of the first definitely adverse physiological symptom for each fish and this was recorded. The symptoms were rapidity or unusual mode of swimming, intense activity and attempts to jump out of the water, distention of the gill covers, excess gulping of the jaws, quivering of the body, and one very important symptom, the loss of equilibrium. Loss of equilibrium was especially noted, for this, as the writer has seen under natural stream conditions, allows fish to be carried down the stream to water that probably is not so toxic and thereby increases their chances of recovery. In their experiments each fish was transferred from the toxic solution under test, immediately after it "turned turtle," to fresh running water.

This procedure is preferred rather than trying to determine the death point for all toxic substances. It affords a means of shortening the time and also keeps the fish mortality at a minimum. As a matter of fact, the idea of Barcroft (3) was followed as to mortality. That is the practice of seeking the concentration and time that produces 50 per cent mortality and in some cases not even waiting for the fish to die. Some naturally occurring substances have been found that require longer time of contact with fish than just a few hours. In the work with these substances the contact time was lengthened to 24 hours.

The fish used, unless otherwise stated, were ordinary fresh water minnows (killies) ranging in length from 1.5 to 3 inches with corresponding weights of 0.75 to 2.5 grams. They were kept in stabilized tap (S. T. hereinafter)[1] water for at least a month before using.

[1] Wherever S.T. is used in this report, it refers to "stabilized tap," the water drawn from laboratory tap and allowed to stand in open vessels at room temperature until it acquired same temperature as room, which averaged 80°F. At this time the free chlorine which was originally present as drawn from the tap, had entirely disappeared. If the water were supersaturated this excess air was removed by agitation. The average alkalinity and hardness of the water used was 35 and 125 p.p.m. respectively.

During this time, some fish died and only the hardy became available. They were fed,[2] during this time once a day and became quite tame, i.e., so as to come to the surface as soon as food was tossed to them. Nothing prevents them from doing this except some disturbing influence in the water. This is an excellent criterion for judging the effect of a foreign substance without waiting for death, for they will jump for the food, after being tamed, every time one tosses in a few crumbs. By the end of the so-called seasoning period the minnows have become quite light in color and have a slight silvery appearance. Any change in color as darkening, is a sign of some disturbing influence being present. Another reliable sign of healthy fish is the stiffness of their fins. These characteristics are mentioned so that by personal observation one can tell if a substance is harmful to fish. Some of the minnows harbor small thread-like worms which probably eventually cause the death of the host. In all cases where the cause of death was obscure the fish were opened to see if worms were present.

Oxygen Saturation Studied

In an investigation of this kind it is desirable to ascertain the fish-water-volume ratio and the oxygen saturation of the water. These values have been plotted as curves and are shown in fig. 1. In about 5 days the water reaches an equilibrium point. Where no fish were present the slight decline is very likely due to the fact the aquarium was exposed to whatever dust might get into it, especially during sweeping of the laboratory floor after working hours. The curve with 4 minnows, starting out with a supersaturated water, did not reach equilibrium in 5 days, but shows that 4 minnows quickly (in less than 24 hours) remove the supersaturated condition. Four minnows in the aquarium correspond to 1.5 gallons of water per minnow and nine to 0.67 of a gallon per minnow.

From these curves it is evident why the amount of water per fish should not be less than 1 gallon where aeration is not used. With this volume per fish the water is able to take up sufficient oxygen from the air to maintain the saturation at approximately 50 per cent. Minnows have been maintained for months at a time with less than this, i.e., when the saturation was 20 per cent. But under this condition a minnow dies every now and then with no other apparent cause. In any experimental work, if oxygen saturation is to be

[2] The food used was a natural fish food prepared for goldfish and purchased in any of the chain stores.

ruled out as a cause of death, it is not advisable to work with a ratio of less than 1 gallon per fish. When 4 minnows are used, the curve shows that in 1 hour there is no appreciable drop. In some of the following tests, upon various chemicals, where 1 hour drops are recorded, the saturation decrease must all be due to the chemical; in other words an immediate oxygen demand is created.

Several aquaria were always in use ranging in capacity from 3 to 6 gallons and the water-fish ratio was maintained at 1.5 gallons per fish. Stabilized tap water was always maintained in the laboratory in open containers for experimental purposes. Unless otherwise stated 4 minnows were always used and paired 2 large and 2 small in the same aquarium. At the same time the rest of the fish not under treatment acted as controls. In some of these experiments a contact period of only 1 hour was allowed and then food tossed to them. After the desired contact period, whether affected or not, they were removed to S. T. water. Groups of fish were not used successively whether affected or normal. This work spread itself over several years and made it possible, where fish were affected and recovered, to keep them several days or even weeks before using them again.

Characteristic Behavior of the Fish

Aside from the aforementioned characteristics and the mortality value for fish, there are two phenomena that cannot be over emphasized and should be especially noted. They are: 1. intense activity (darting around with attempts to jump out) and 2. inability to swim in a normal position, i.e., loss of equilibrium or what is commonly called in aeronautics 'doing stunts.' This results finally in their sinking to the bottom of the aquarium. If they were removed to other water not containing the substance under investigation they soon recovered their balance, going through the same antics during recovery with the exception of not darting around. They soon appear perfectly normal. This characteristic of 'doing stunts' is of great importance because upon several occasions during the drought periods, in various sections of the country, streams caused fish to do exactly this and as far as the writer has been able to ascertain, the cause is still a matter of conjecture.

During this work in our laboratory this condition has been exactly duplicated with the result that in the mind of the writer, there is no doubt as to the cause in one stream. This may possibly answer the

question for all streams during drought periods, where the cause has been obscure or a matter of supposition. In our case the blame was at first assigned to some industries along the stream. Actually the cause has been due to nature itself and appears only once in a while.

The total number of trials made upon each substance and the detailed data recorded are so voluminous that it is well beyond the scope of this paper to record all of it. Only the results will be given

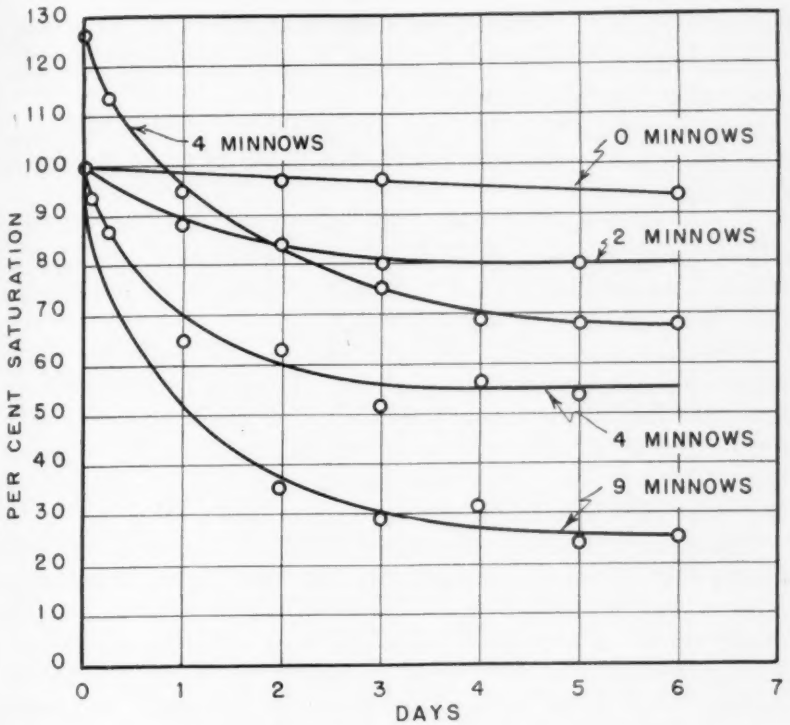

FIG. 1. Daily Oxygen Saturation for Minnows at Room Temperature

with the hope that they may enlighten others interested in work of this kind.

It was not intended to use exceptionally high doses of chemicals in this work, but rather doses that might approximate the dilution of the most voluminous effluent after it has entered the stream under consideration. The question of lethality was kept in mind but only determined for the substances that were possible pollutants of the

stream or producing effects similar to river conditions. It was also desirable not to lose too many fish in order to arrive at some academic figure for the death value, rather to notice some effect on the fish in a short time that might lead to death after longer periods of contact, such as not eating freely. There are substances for which death values were determined because they were of utmost importance in arriving at the cause of the great fish catastrophe of the drought years.

Chemical Salts and Liquids

In the following work all chemically pure (C. P.) chemicals were used unless otherwise stated.

Acetone ($(CH_3)_2CO$). In a 1:1,000 dilution of acetone the aquarium had a faint sweet odor and the fish during 24 hours showed no ill effects.

Acetonitrile (CH_3CN). One grain per gallon shows no harmful effects during 24 hours' contact. Since this chemical contains nitrogen it was diluted 1:5 and 1:50 with distilled water and cyanide tests performed with a negative result.

Aluminium Sulfate (17 per cent Al_2O_3). One grain per gallon produced a coarse floc in the aquarium. This concentration did not affect the fish during 1 hour's contact after which time they were removed to S. T. water and were still unchanged on the following day. The aquarium water after adding alum had an alkalinity of 42 p.p.m., carbon dioxide content of 4 p.p.m. and a pH of 7.3.

This absence of adverse effect upon fish is not surprising, for in the mixing chambers of the average rapid sand filter plants, where higher doses of alum are used than here recorded, fish life may be observed at any time. As long as the alum dose does not carry the water to acidity, the common river types of fish should have no difficulty existing even if the water contains floccy aluminium hydroxide.

Arsenic Trioxide (As_2O_3). One grain per gallon did not affect them after 1 hour's contact and when transferred to S. T. water they were still normal the next day.

Blas (4) reports a high fish mortality in the Odiel River, Huelva, Spain, which he attributes to As_2O_3 and low pH. It should be noted that Huelva is the location of the copper pyrite mines and a body of water draining this section naturally would not only contain arsenic but also sulfur (as acid mine waste), copper, iron and other metals that would add to its toxicity.

Benzaldehyde (N. F. Liquid, not less than 85 per cent C_6H_5CHO). This artificial oil of bitter almonds was added to the aquarium so as to produce a concentration of 1 grain per gallon and gave the water a decided odor of bitter almond oil. Fish, in this concentration, would not eat during 24 hours but there was no mortality. The oxygen saturation did not show any abnormal drop. In a lower concentration ($\frac{1}{8}$ grain per gallon) and after 24 hours' contact, the odor was no longer that of almond oil but had changed to woody.

Cresol (U. S. P. Sp. Gr. 1.35). What little physiological effect is produced, is very similar to phenol for the same concentration, even to the intensity of the taste produced when the aquarium water is chlorinated.

Copper sulfate ($CuSO_4 \cdot 5H_2O$). One grain per gallon in 1 hour showed some effect by making the fish sluggish. They would come to the surface of the water and then settle back in a more or less vertical line. While settling back they were just a little arched (convex). They could easily be picked up, the large ones seemed to be affected the most, but there was no loss of balance. When removed to S. T. water 50 per cent did not survive. This concentration of copper sulfate gave a faint blue color in a Nessler tube when ammonia was added. Hydrogen sulfide water gave a brown color whereas potassium ferrocyanide gave a clear reddish-brown color.

In a concentration of 0.25 grain per gallon for 1 hour, the fish became shy and they refused to eat, so that even in this concentration the effect is quite apparent. Ammonia did not produce a blue color whereas hydrogen sulfide showed a slight discoloration.

The average value of several determinations producing 50 per cent mortality in 24 hours is 1.3 p.p.m. of copper sulfate.

Dextrose ($C_6H_{12}O_6$). Anhydrous dextrose was added to the aquarium so as to produce a concentration of 1 grain per gallon and did not affect the fish during 24 hours. At the end of this time the water had a faint woody odor.

Ferrous Sulfate ($FeSO_4 \cdot 7H_2O$). One grain per gallon during 1 hour did not produce any visible effects and the fish acted normally. This experiment affords an excellent opportunity to observe any effect produced by a sudden change in dissolved oxygen. The dissolved oxygen dropped during this hour from 92 per cent saturation to 16 per cent, due to the fact that ferrous iron is oxidized to ferric iron. Then the fish, at the end of this hour were put into S. T. water where the oxygen saturation was again 92 per cent. They showed no

distress after the change. Even after 24 hours in S. T. water they were still perfectly normal. This is not cited to prove they could live indefinitely at 16 per cent O_2 saturation but rather that the rapid change in either direction was neither harmful nor noticeable.

Potassium ferricyanide added to aquarium water containing only 0.25 grain per gallon produces no color reaction but if acidulated with sulfuric acid a very faint green color develops.

Formalin (35–40 per cent HCHO). A 1:240 dilution of formalin gives the aquarium a decided odor of formaldehyde. During the first half-hour's contact the fish were very much stimulated, tried to jump out and soon settled to the bottom. No unbalanced motion was exhibited and no eye dilation was observed. They did, however, become very dark in color, like black bass. All were affected similarly and after one-half hour's contact they were removed to S. T. water and were dead in 2 hours.

Even a 1:2,400 dilution produced a faint sweet odor and a faint sweet taste when chlorinated. This dilution affected the fish so that they would not eat after 1 hour's contact. Obviously this concentration is harmful.

Formalin has been known to get into a river by accident from a synthetic resin plant and at the time caused considerable fish mortality.

Lead Arsenate ($PbAs_2O_3$). One grain per gallon makes the aquarium slightly milky due to its insolubility and at this concentration no noticeable effects were observed during 1 hour.

Mecuric Chloride ($HgCl_2$). One grain per gallon during 15 to 30 minutes produced activity in the fish. They tried to jump out of the water, then settled to the bottom as if lifeless. Upon removing to S. T. water the same kind of activities occurred and finally they reached the bottom with mouths open and all were dead the next day.

A 0.25 grain per gallon concentration produced activity in 15 to 30 minutes, but by the end of 1 hour they were normal with one exception—they would not eat. This concentration is very near the lethal dose for minnows.

Naphtha. A 1:2,400 dilution is really not a dilution, for the naphtha floats on the surface of the water and evaporates in about 5 minutes. The water has an odor of naptha. Fish placed in this water for 15 minutes would not eat but showed no other signs of distress during 24 hours. After 24 hours they ate sparingly. The oxygen saturation was not changed but the naphtha undoubtedly

produces some temporary effect. Due to its high volatility, it does not remain in the water and thereby gives the fish a chance to recover.

Naphthalene ($C_{10}H_8$). One grain per gallon produces a suspension as it is not soluble in water. This imparts a rather strong odor of napthalene to the water and at the end of 1 hour the fish would not eat.

The fish showed no visible effects when subjected to a concentration of 0.25 grain per gallon for a period of an hour. The water, even at this concentration, has a slight odor of naphthalene. Even when a 1:10 dilution of this is chlorinated it gives a slight medicinal taste. Those fish that would not eat when subjected to 1 grain per gallon were transferred to S. T. water and the next day were perfectly normal.

Phenol (C_6H_5OH). Observations by men doing river patrol work on industrial streams show that phenol is not a very toxic fish poison and the literature contains many references concerning phenol in streams. Stooff (5), a scientific member of the *Landesanstalt*, states that phenol up to 10 p.p.m. is quickly destroyed biologically in natural waters, but wastes entering a river should not exceed this value after dilution if the river contains fish. If it is to be used as a water supply, higher dilutions are necessary. Bach (6) investigated the disappearance of phenol in water and showed that a reduction of 0.7 p.p.m. of phenol per day could be obtained when using 8 goldfish in a large tank (210 liters). As the phenol disappeared an additional amount of phenol was added to keep the concentration constant. He concluded that this was an astounding reduction and believes this gives some reasons to expect that in quiet or slowly flowing waters, assuming no sludge deposits, self-purification is more rapid than in rapidly flowing waters. He also noted that of 15 fish placed in water containing 15 p.p.m. phenol, 12 fish were living after 46 days. The fish were then killed and cut open. A weak odor of phenol could be detected in the fish. Eldridge (7) showed that 20–25 p.p.m. pure phenol in an aerated sample of water will kill fish, while in an non-aerated sample 10–20 p.p.m. kill them.

With all this information and that compiled by Ellis (1), the present author did not feel justified in trying to determine the phenol death-point for minnows. For that reason, only a single run using 1 grain per gallon was made and this concentration did not cause any mortality during 24 hours. There is one important thought to bear in mind, however, and that is, before anywhere near a lethal concen-

tration could be accumulated in a stream (if the stream is used as a water supply) the odor and taste of the water when chlorinated, would lead to its immediate detection. It is interesting to speculate as to what is formed when water containing phenol is chlorinated, for most investigators are of the opinion that so-called chlorphenols are formed. From a recent investigation by the author, it was observed that tetra and pentachlorphenols do not produce an odor or medicinal taste when added to water. As a matter of fact, pentachlorphenol in a concentration of 1 grain per gallon gives no odor or taste and neither did it cause a false residual with ortho-tolidine.

Potassium Cyanate (KCNO). One grain per gallon produced no noticeable effects upon the fish during 24 hours, after which time they were transferred to S. T. water and were still normal the next day. The decrease in oxygen saturation during the 24 hours was only 16 per cent.

Potassium Ferricyanide ($K_3Fe(CN)_6$). One grain per gallon showed no effects during one hour. The fish were then removed from this water to S. T. water and were perfectly normal the next day. Ferrous sulfate gives a blue color to 50 c.c. of this water and the limit of sensitivity was $\frac{1}{8}$ grain per gallon.

Potassium Ferrocyanide ($K_4Fe(CN)_6 \cdot 3H_2O$). One grain per gallon produced no noticeable effects upon the fish during 70 days. In about 4 hours after adding the ferrocyanide the water takes on a very slight green color due to traces of iron in the water. This concentration of ferrocyanide is easily detected by adding ferric chloride which produces a blue color immediately. During this long run the volume of water decreased by natural evaporation about 50 per cent. Tests from time to time for ferrocyanide showed that it was decreasing until at the end of 70 days there was practically no ferrocyanide present that could be detected by the ferric chloride reagent. During all this time it is safe to say that no cyanide was formed, for the fish showed no ill effects.

Potassium Sulfocyanide (KCNS). Aquarium water before adding sulfocyanide and fish contained a dissolved oxygen content of 76 per cent, pH 7.0 and an alkalinity of 30 p.p.m. After adding 10 grains per gallon of KCNS and 4 minnows the D. O. dropped in $\frac{3}{4}$ of an hour to 57 per cent saturation and remained at this value for 7 days. During the third day 2 minnows became wobbly and sank to the bottom of the aquarium (no initial activity), the other fish being perfectly normal. The water at this time had a pH of 6.9

and alkalinity of 30 p.p.m. The 2 minnows that were wobbly were removed to S. T. water and never recovered. Autopsy showed no worms present. Between the seventh and ninth day the D. O. decreased to 41 per cent saturation and the remaining 2 minnows followed the course of the first two and did not recover in S. T. water. The autopsy showed no worms present. During this time there was a decrease in sulfocyanide present, with a corresponding increase in free ammonia and sulfate.

This salt does not produce in the fish any initial activity and there is no recovery. It acts in the fashion of a slow poison and once it affects the fish they cannot recover even in other water. The change in oxygen saturation is not the cause of death.

Sulfocyanide is a common constituent of gas-house waste liquor and should not be permitted to flow into a stream for it may go down the stream and get into the intake of a purification plant. In so doing it not only imparts color to the water if iron is present but produces an abnormally high chlorine demand, even in very small quantities, thus preventing the chlorine from killing the bacteria that might be present in the water. Even as little as 1 p.p.m. KCNS has a demand of 20 lb. chlorine per million gallons.[3]

On several occasions the writer has experienced having a waste containing sulfocyanides find its way into the raw water supply and even with pre-chlorination, rapid-sand filtration and post-chlorination the residual chlorine dropped to zero. At another time the raw water contained 0.24 p.p.m. of CNS and the filter effluent 0.18 p.p.m. CNS and even though the normal chlorine rate of application had been doubled, there still was no residual chlorine present.

Bacteriological samples collected at this time showed coliform organisms present in 10 c.c. portions. This is an example of how serious a menace sulfocyanide wastes may become to the purification plant operator and how they can create a potential health hazard. In this low concentration any iron present will not react to give a

[3] Chlorine demand as recorded throughout this report, consisted of 10 minutes contact of water with chlorine water at room temperature and the measurement of free chlorine by O. Tolidine. A series of concentrations were always run and a curve plotted, selecting from this curve the quantity corresponding to a residual of 0.12 p.p.m. Blanks were run upon the water before the chemical to be investigated was added. The strength of the chlorine water was determined using distilled water and O. Tolidine, an average of several determinations upon varying quantities of chlorine water was then used.

color that would show its presence and the oxygen consumed determination would be of little value, for 1 p.p.m. of KCNS only increases the oxygen consumed value by 0.5 p.p.m. A slow-sand filter plant using the same raw water at the very same time showed no CNS in the filtered chlorinated effluent. No unusual chlorine demand was created, so the filters, not the chlorine, actually removed the CNS. Bacteriological tests upon this water showed low counts and no coliform organisms present in five 10 c.c. portions.

Brun (8) studied the relative toxicity of the thiocyanate ion and reported that NaCNS of 0.04 N killed fish in 2 hours.

It is interesting to note that thiocyanate is formed in the animal body, for Lang (9) reports CNS elimination of 3-10 mg. per day of which 90–95 per cent occurs in the urine.

Potassium Sulfocyanide (chlorinated). As sulfocyanide was found to have a very high chlorine demand one became curious to know just what takes place when chlorine is added to water containing sulfocyanide.

Sulfocyanide was added to aquarium water so as to produce a concentration of 6 p.p.m. of KCNS and then strong chlorine water added until the demand was satisfied, i.e., leaving a residual of 0.02 p.p.m. of chlorine. Direct nesslerization of samples before and after adding chlorine showed no change. A test for sulfocyanide after chlorination using ferric chloride showed it to be absent, whereas a test for cyanide showed it to be present. Hence this reaction probably took place:

$$KCNS + 3\ Cl_2 + 4\ H_2O = HCN + KHSO_4 + 6\ HCl$$

Six p.p.m. of KCNS should produce a toxic medium. Without making a quantitative determination for cyanide, fish were introduced into the aquarium and manuevers observed identical to those produced when runs were made using $\frac{1}{4}$ grain per gallon of NaCN. All fish recovered when removed to S. T. water. Here is a case where a non-toxic substance was converted into a very potent fish poison. When the nitrogen is acted upon by the biologic flora and the oxidation is slow, the nitrogen then appears as ammonia as indicated in the previous experiment.

Selenous Acid (H_2SeO_3). This is a colorless crystalline substance soluble in water, producing an acid reaction. One grain per gallon of selenous acid decreased the alkalinity of aquarium water only 4 p.p.m. and did not in any way affect fish during 24 hours' contact.

Sodium Cyanide (NaCN). Sodium cyanide in a concentration of 0.3 p.p.m. does not affect the fish during 24 hours' contact. A concentration of 0.4 p.p.m. caused the fish to push their noses out of the water and dart around on the surface. By the end of 1 hour they would not eat and lost whatever food they had eaten. Some of them almost lost their balance but in 4 hours all seemed to recover and at the end of 24 hours were perfectly normal. They were removed and fish not used before put into this same water and no effect was noticed. Here is a case appearing to indicate that any effect the cyanide produces upon fish is destroyed in about 6 hours.

Concentrations of 0.5, 0.6 and 0.7 p.p.m. produced 25 per cent mortality in 24 hours. A concentration of 0.8 p.p.m. made the fish dart around on the surface, then swim lazily along upside down and upon their sides, and finally sink to the bottom of the aquarium after 2 hours' contact. They became very dark in color somewhat like black bass. Their eyes were very much dilated, the pupil or dark part occupying 80 per cent of the space allowed for the eye whereas normally it appears to be less than 50 per cent. At the end of 24 hours the mortality was 100 per cent. The concentration producing 50 per cent mortality is obviously between 0.7 and 0.8 p.p.m.

The most significant reaction of fish affected by cyanide is, if removed just as soon or not long after they lose their ability to swim in a normal way to water not containing cyanide, they soon recover and become perfectly normal healthy fish and will continue to remain that way. The time of recovery is about equal to time of exposure.

The ability to recover from what seems to be death from cyanide if removed to a healthy environment, was noted by Barcroft (*loc. cit.*) in his work with hydrogen cyanide gas upon animals. "In his dog-man experiment, when the dog was thought to be dead and set aside for burial, the dog did in point of fact recover and was found walking about the next morning and showed no further symptoms."

In the writer's work using cyanide, larger fish of different variety (river catfish, 4–6 inches long) were also tried and the quantity required to produce the same effect as with minnows was about the same. Still larger fish were used and in this case river carp were selected, ranging in size from 12 to 15 inches and 1.5 to 2.5 lb. This is a very hardy species of fish and when placed in a 350-gallon tank containing sodium cyanide in a concentration of 0.25 grain per gallon,

they were affected in about the same time and the same 'stunts' were noticed as with the small minnows. All recovered after having been placed in S. T. water. Apparently the size of the fish is not an important factor, but rather the concentration of the toxic substance in the water.

The action upon fish is quite similar to that upon humans for textbooks upon pharmacology state that cyanide first excites the central nervous system and then paralyzes. Eye dilation is very noticeable.

Sodium Cyanide (Chlorinated). Several runs were made using water which contained a definite amount of sodium cyanide, to which was added a small amount of strong chlorine water so as to produce a final residual chlorine value of 0.10 p.p.m., after satisfying the demand. Then the cyanide content of the water was determined which showed that for all practical purposes there was no change in the cyanide content, but rather high nitrites were observed. Even with the fish in this water the diminution in free chlorine in 1 hour was only about 20 per cent so that it could be considered chlorinated as one usually thinks of chlorinating a water. The cyanide content during the same hour showed practically no change from that originally obtained. The fish showed similar characteristics as when cyanide is used alone but when stupefied by a concentration of 0.25 grain per gallon of NaCN their chances of recovery were not good, as most of them even though removed to S. T. water never recover. It seems permanently to affect them and the potency of the cyanide is doubled, i.e., 0.3 p.p.m. NaCN when in contact with chlorine gas produces about the same result as 0.6 p.p.m. alone. At this low concentration fish that were affected and immediately removed to S. T. water did recover but required several days for recovery. A significant feature is that if water containing cyanide is chlorinated to a value considered to be usual practice, no guarantee exists that the cyanide is destroyed, and surely not the toxicity.

Sodium Fluoride (NaF). One grain per gallon produces no visible effect during 1 hour's contact and when the fish are transferred to S. T. water they are still alive after 24 hours.

Sodium Nitrite ($NaNO_2$). One grain per gallon produces, in the aquarium water, 4 p.p.m. of nitrite nitrogen. Fish, in this water during 24 hours were perfectly normal and when transferred to S. T. water they were still alive after 24 hours. During the 24 hours' contact, the nitrite nitrogen decreased 1 p.p.m. and the oxygen saturation decreased only 18 per cent.

In natural streams high nitrites do not exist unless the oxygen content of the water is low and then it is rarely as high as 4 p.p.m. So it is quite probable that any distress in fish is due to the low oxygen saturation and not to relatively high nitrite content.

Sodium Nitroprusside ($Na_2Fe(CN)_5(NO)\cdot 2H_2O$). One grain per gallon produces no ill effects during 1 hour's contact. With a concentration of 0.25 grain per gallon a purple color, which fades in 5 minutes, is produced when 100 c.c. of this water has added to it 1 c.c. of 10 per cent sodium sulfide solution.

Sodium Sulfide ($Na_2S\cdot 9H_2O$). One grain per gallon (calculated as Na_2S) produced a very strong odor of hydrogen sulfide. When this water is diluted 1:40 the cold odor is just about perceptible in a covered flask. Upon acidulation it becomes very pronounced. It is quite possible to detect the characteristic odor of H_2S when only 0.01 p.p.m. of Na_2S is present, provided the solution is acidulated. The aquarium water had a total alkalinity of 54 p.p.m. of which 5 p.p.m. was phenolphthalein alkalinity. The water takes on a distinct amethyst color when a little caustic is added followed by sodium nitroprusside (10 per cent) reagent. The alkalinity of the aquarium water before adding sodium sulfide was 43 p.p.m. with no phenolphthalein alkalinity. It also had a dissolved oxygen content of 6 per cent above saturation. This supersaturation was due to drawing the water cold and allowing it to stand until it reached room temperature without agitation.

When the fish were placed in the water containing sodium sulfide the oxygen saturation at the end of a half-hour had dropped to 21 per cent. It then slowly rose to 30 per cent in the next quarter-hour and on the following day was up to 52 per cent. The fish showed no effects in 1 hour but soon thereafter were swimming near the surface as if trying to get air. They were easily frightened and ate only sparingly. In 5 hours they were about the same, but after 24 hours all were perfectly normal and ate freely. By this time the aquarium had lost its hydrogen sulfide odor and even when the water was tested in a flask having a cover, it had only a very slight sulfide odor showing that the sulfide in the short space of 24 hours had practically all been oxidized to sulfate. A smaller concentration of sodium sulfide was tried and did not produce any noticeable effects upon the fish, so the above concentration, is just about the limit when added at one time. Of course a smaller continuous dose would undoubtedly keep the oxygen saturation quite low and probably be fatal to fish. This

work, although intended to show the effect of sodium sulfide, went even further by showing how the fish can endure a sudden decrease in oxygen saturation. Sulfides in water produce a rather high chlorine demand, for even as small as 1 p.p.m. of Na_2S has a demand of 10 lb. per million gallons.

Sulfuric Acid (H_2SO_4). Sulfuric acid was added to the water so as to produce an M. O. acidity of 26 p.p.m. In this concentration of acid at the end of 15 minutes the fish were slightly accelerated with a roller-coasting motion and during 1 hour the motion was about the same. They would not eat and could easily be picked up. When transferred to S. T. water they were perfectly normal the next day. Acidity to M. O. of 5 p.p.m. produced no visible effects during 1 hour, other than the fact that the fish would not eat. Any fish that will not eat in a particular environment certainly are not going to survive, so it appears that even the slightest acidity is detrimental to fish life, at least minnows.

Zinc Chloride ($ZnCl_2$). One grain per gallon showed no effects during 1 hour and when transferred to S. T. water fish were perfectly normal on the following day. When potassium ferrocyanide reagent is added to this water it produces a milky turbidity.

Gases

Acetylene (C_2H_2). Calcium carbide was added to water to the extent of 1 grain per gallon calculated as CaC_2. This gave the aquarium a slight acetylene odor and phenolphthalein alkalinity of 11 p.p.m. Fish in this water were perfectly normal during 1 hour's exposure.

Air (Dissolved Oxygen). An aquarium in which catfish had died showed zero per cent oxygen saturation with a very fishy odor. Minnows were added to this water, having come from water with an oxygen saturation of 28 per cent. They seemed to do well with only one decided characteristic which was poking their noses out of the water almost continuously. After being in this water for 24 hours the mortality was 50 per cent and at this time the dissolved oxygen was still zero. This is not cited to show that some fish can survive in water with practically no oxygen but rather to show that the minnow is a rather hardy species.

In the following experiments common goldfish purchased in a chain store, ranging in size from 2–4 inches, were used. The change from minnows to goldfish was made because most people use this

variety for household pets and also think of them as being rather sensitive to any changes in the air content of the aquarium.

Oxygen saturation values between 100 and 110 per cent produced no visible air bubbles in the aquarium or on the fish. The residual chlorine in this water was 0.05 p.p.m. During 24 hours the fish in this water appeared perfectly normal. With oxygen saturation values between 110 and 120 per cent, the air in the aquarium is just about visible with slight effervescing. The residual chlorine then was averaging about 0.11 p.p.m. and fish placed in this water for 48 hours collected only a few air bubbles on their body. Their dorsal fins were erect and they seemed to be perfectly normal in every respect.

By heating the incoming cold water, already at or near the saturation point and passing it slowly through the aquarium, it was possible to maintain the oxygen saturation during 24 hours between 120 and 126 per cent saturation and at the same time the chlorine residual remained at 0.18 p.p.m. The fish were taken from water containing zero chlorine and 19 per cent oxygen saturation (they had been in this water for several days) and placed in the supersaturated water as just described. In 15 minutes they were almost entirely covered with air bubbles, even on their eyes and fins. They found it difficult to stay in the water, for the air made them float like a cork. Their dorsal fins were very limp which is a good indication that they were not in a very satisfactory environment. The aquarium was effervescing like soda water due to the continuous liberation of air from the water. In 13 hours 75 per cent of them were about powerless and floated on the surface. These were removed to other water where the oxygen saturation was 45 per cent and recovered in a very short time. By the end of 24 hours the last fish was in a helpless state and was removed. Immediately the dorsal fin became erect, and lost its air bubbles and once again the fish was perfectly normal.

Goldfish that had been kept in circulating water at 23°C. for several days were placed in circulating water having a temperature of 10°C., a chlorine value of 0.10 p.p.m., and an oxygen content slightly below 100 per cent saturation. Immediately their normal activity was slowed down and dorsal fins became rather limp. They were kept at this temperature for 72 hours and all during this time the oxygen and chlorine values were fairly constant. Their movements were rather sluggish and they ate only sparingly but showed no signs of distress. After 72 hours in this water all were transferred to water

of a temperature of 34°C. which was previously boiled and allowed to come to this temperature. This water now had a saturation value of 39 per cent, carbon dioxide of zero, chlorine of zero and pH of 7.8. Immediately they looped-the-loop and darted around with terrific speed and tried to jump out of the aquarium. Soon they were off balance and their motions were very similar to that produced by cyanide, only with no giving up of their stomach contents.

After a contact of 1 minute the smaller goldfish were floating on their sides and were removed to S. T. water in which they recovered in a few hours but did not go through any antics during recovery. The fish just righted themselves like a sailboat when the wind stops. The larger fish seemed to adjust themselves better and in several minutes were able to tolerate this water. In 1 hour the aquarium water still had a saturation of 39 per cent with zero carbon dioxide, pH of 7.6, and the larger fish were perfectly normal. In 11 hours the water had reached room temperature and in 24 hours these fish were still perfectly normal. It is quite likely that the 2 smaller fish if left in this water would have died, for they were not in very good condition when removed to the other water. Hence, fish swimming into a warm effluent from cold water are likely to be killed if not able to swim out of it soon enough.

In this work with goldfish it appears that the conditions that affect them are: a sudden rise in temperature to an abnormal degree, and air-lifting caused by oxygen supersaturation, which makes them float like a cork. The larger fish are more resistant as far as temperature is concerned, apparently better able to adjust their air sacs to this sudden rise in temperature.

During all the experiments upon goldfish it was noted that they will push their noses through the surface when the oxygen content of the aquarium is low as well as high, apparently in the first case to take in more air. In the second case they probably want to expel air.

Ammonia (NH_4OH). One grain per gallon calculated as NH_3 affected the fish after 1 hour's contact only to the extent of making them so they would not eat and would swim close to the surface. If left in this water continuously it is quite probable that death would result. Upon transferring the fish to S. T. water they were perfectly normal in 24 hours. This concentration of ammonia gave the aquarium water a phenolphthalein alkalinity of 27 p.p.m. A con-

centration of 0.25 grain per gallon did not affect them during 1 hour's contact and produced in the water a very slight phenolphthalein alkalinity which soon dissappeared.

Carbon Dioxide Free Water. This was produced by adding caustic soda until the aquarium had a phenolphthalein alkalinity of 13 p.p.m. with an oxygen saturation of 61 per cent. Fish left in this water for 2 hours were perfectly normal.

Chlorine (Cl_2). Fish that were not in water containing chlorine were placed in water containing 0.3 p.p.m. of free chlorine and during 2 hours' exposure showed no signs of distress with the residual chlorine still at 0.3 p.p.m. At the end of this time they were removed to water having no free chlorine and appeared perfectly normal for many days thereafter.

The question of free chlorine in water killing fish has been a much discussed one from time to time. Any filter plant operator, where chlorine is applied to the water before it goes to the coagulation basin, will find fish swimming around with chlorine residual of at least 0.2 p.p.m. Goldfish have been kept in running water for many days with the residual chlorine between 0.10 and 0.20 p.p.m.

Hydrogen Sulfide (H_2S). Strong hydrogen sulfide solution was made by passing the gas into water and then portions of the strong solution were added to the aquarium. With an initial oxygen saturation of 106 per cent and then adding sulfide water so as to produce 5 p.p.m. H_2S (which gave the aquarium a strong sulfide odor), the fatality of fish in this water for 24 hours was 50 per cent. At this time the oxygen saturation was 24 per cent and H_2S concentration was 1.4 p.p.m. During the first half hour the oxygen saturation decreased to 42 per cent and the aquarium became quite turbid due to colloidal sulfur. Sodium nitroprusside test using caustic soda gave an amethyst color. By the end of 6 hours the oxygen saturation showed 36 per cent.

A concentration of 6 p.p.m. of H_2S produced a fatality of 100 per cent, so it was decided to try 4 p.p.m. and at this value no fish were killed during 24 hours' exposure, neither did they show any signs of distress. Hydrogen sulfide produces some of the effects of cyanide but during the recovery period the fish do not go through the same antics as those recovering from cyanide. Cyanide also produces an initial activity of quickly darting across the surface of the water which is not seen when fish are affected by hydrogen sulfide. One

thing is sure and that is, the amount of H_2S which affects fish is so high, that a body of water containing it would produce such a disagreeable odor, that no one would care to be in its vicinity for any length of time. Stroede (10) found the m.l.d. of H_2S for trout to be 1 p.p.m. and for carp 8–12 p.p.m.

Illuminating Gas. Illuminating gas was passed into aquarium water through a diffuser until saturation was established. This imparted to the water a very strong gassy odor and taste. The water contained plenty of oxygen and was alkaline to methyl orange. When fish were placed in this water they immediately darted around at all depths at a speed that approximated that produced by cyanide but neither lost their balance nor swam upside down. In less than 5 minutes they were down on the bottom and lay on their sides. In 15 minutes the fish looked dead and their tails were bent at an angle of 45 degrees with their body. Upon removing to S. T. water they never recovered. No eye dilation was produced and they did not become dark in color as when exposed to cyanide. The water did not give a chemical reaction for cyanide.

When a 1:10 dilution of the above water was made, the water still had a cold odor of strong gassy and a slight gassy taste when chlorinated. Fish put into this water for 5 minutes ate only sparingly. In 1 hour they were nervous and shy and still hesitant about eating. In 2 hours one large fish was standing on its nose and another one had a bent tail. By the end of 24 hours all were normal in every respect. This is probably as strong a concentration of illuminating gas as they can tolerate. Even at the end of 24 hours the aquarium water had a strong gassy odor but the taste was only just about noticeable.

Even though no positive cyanide reaction was obtained in water saturated with illuminating gas, other workers, like Hitchcock (11) *et al.*, record soil being made toxic by illuminating gas containing HCN. Gales and Pensa (12) determined quantitatively small amounts of cyanide from the powder that collects on the copper coils of a gas heater. Hence hydrogen cyanide in illuminating gas is not uncommon.

Methane (CH_4). Methane gas was bubbled into the aquarium water by means of a diffuser until saturated. Fish placed in this water showed no noticeable effects during 2 hours contact. The water had a sweet taste when chlorinated.

Industrial Wastes

Wastes were tested only from industries that might be a pollutant of our eastern streams, so the list does not include all the possible wastes throughout the country. These wastes were described by Jenne (13) and the sanitary analyses shown in his work. In the toxicity studies on these trade-wastes the concentration of the waste in the aquarium is such as to approximate the dilution by the river of the effluent having the greatest volume, allowing for low flow in the river and a concentration of the effluent by several hundred per cent. Then a constant ratio of dilution was used on the others even though their volume was much less. A contact time of 1 hour was used rather than a longer time because if no effect is shown in this time, it is likely that the natural purification agencies of the stream would, after this time, start to assimilate it. Whenever 2 dilutions were necessary it is debatable whether this waste should be permitted to run into the stream.

Ammoniacal Liquor from Hydraulic Main of Coke-Gas Plant (No Tar). This is an amber colored liquor with an ammoniacal odor and when diluted 1:500,000 gives a very faint medicinal taste when chlorinated. The liquor showed no reaction for ferro- or ferri-cyanides, a faint positive test for cyanide and decided tests for sulfocyanide. A casual glance at the constituents in the waste liquor from a semi-direct by-product coking plant will show why this waste is toxic: phenols, 1.10; cyanide (as HCN), 0.06; and sulfocyanide (as HCNS), 0.60 as grams per liter.

When diluted 1:240 in the aquarium it gave the water a faint yellow color and fish put into this water showed the characteristics of cyanide poisoning, approximating that produced by 0.5 p.p.m. of NaCN. This concentration is quite toxic. The aquarium water had a distinct odor similar to the original liquor and imparted to the aquarium a phenolphthalein alkalinity of 19 p.p.m. Tests for dissolved oxygen showed no appreciable reduction at the end of 1 hour. After the fish had 1 hour's contact they were removed to S. T. water and showed during recovery the same characteristics as those recovering from cyanide treatment. All fish were perfectly normal the next day. A 1:2,400 dilution did not affect the fish during 1 hour's contact. This liquor should not be permitted to enter a stream.

Waste Liquor from Coal Tar Products Plant. This is an orange

opaque liquor with tarry residue floating on it, having a strong odor of naphthalene. It gave a slight medicinal taste when diluted 1:25,000 and chlorinated. A 1:2,400 dilution produced in the aquarium a slight odor of naphthalene. No immediate reduction in D. O. occurred and no phenolphthalein alkalinity was present. During 1 hour the fish were perfectly normal with only one exception which was that they would take in food but immediately eject it. This is a rather high concentration and should not enter a stream.

Cyanogen Scrubber Sludge Liquor from Gas Plant. This liquor is quite viscous and black in color with a strong odor of gas-house waste. A 1:240 dilution made the aquarium water black and opaque, so the fish could hardly be seen. The water had a strong odor similar to the original sludge. Fish in this water swam on the surface poking their noses out most of the time as if seeking air. They became entirely covered with a black substance similar to sulfide of iron. After 1 hour's contact 2 looked dead and when transferred to S. T. water they did not recover, so at this dilution the mortality was 50 per cent. The fish that died showed no symptoms such as that produced by cyanide. An autopsy performed on these fish showed one of them to contain a live worm. A 1:2,400 dilution during 15 minutes contact made the fish go through roller-coasting motions. Except for this, they were perfectly normal, even after a contact of 1 hour. This is about the strongest concentration they can tolerate.

Dairy Waste. This is a white opaque liquor with no odor. A 1:240 dilution produced in the aquarium a slight milky appearance. Fish placed in this water for 24 hours were perfectly normal at the end of this time. During the 24 hours the oxygen saturation had decreased 57 per cent and without the waste the drop was only 35 per cent. The fish were not removed from this water for several days and gradually during this time the water became clear, showing that the fish probably consumed the suspended material.

Distillery Waste. This liquor is brown with quite a little sediment and has a characteristic sweet odor. A 1:240 dilution produces a reddish-brown colored water with a turbidity and a strong odor like the original waste. The oxygen saturation decreased 28 per cent in 1 hour so that the waste produced an immediate demand. At the same time the alkalinity had increased 13 p.p.m., with a carbon dioxide increase of 3 p.p.m. . Fish in contact with this water for 1 hour showed no visible effects,and when transferred to S. T. water

were still perfectly normal on the following day. Even though in this experiment no effect was noticed because the initial oxygen content was high, it is entirely possible that a 1:240 dilution would mean high fish mortality if added to a stream with low oxygen saturation. If the stream to which this waste is added does not have sufficient oxygen to take care of the immediate demand, then the oxygen content would drop to zero. A dilution of 1:240 which was then void of oxygen remained with zero oxygen for over 7 days showing that it is difficult for a body of water to recover from the effect of this material.

Paper Plant White Water. This liquor is white and contains white paper pulp which quickly settles. A 1:240 dilution produces a white turbidity and fish subjected to it for 1 hour would not eat. No other sign of distress was seen and when transferred to S. T. water they soon ate and in 24 hours were still alive. A 1:2,400 dilution does not affect them in any way during a contact of 1 hour. Water containing this waste has a rather high oxygen consuming power as measured by permanganate.

Pickling Liquor. The liquor when collected is black and opaque. Upon cooling, an appreciable amount of green ferrous sulfate crystals are deposited. A 1:240 dilution makes the aquarium have a dirty yellow color and the water is still opaque. Total iron content at this dilution was 470 p.p.m. with an acidity of 30 p.p.m. The iron content being so high made it rather difficult to determine the oxygen content at this dilution. Fish placed in this concentration for 15 minutes would not eat and after a contact of 1 hour they were inactive. Upon removing them to S. T. water they were still inactive and did not look as if they would recover. At the end of 24 hours in S. T. water the mortality was 50 per cent. A 1:2,400 dilution made the aquarium look like it contained 'circus lemonade' due to the formation of ferric iron and produced an immediate oxygen demand of 1 p.p.m., so the original liquor has an oxygen demand of 2,400 p.p.m. The alkalinity decreased 14 p.p.m. leaving a residual alkalinity in the aquarium of 14 p.p.m. Fish in contact with this water for 1 hour were perfectly normal.

Purging Water from Purifying Boxes of Gas Plant. This liquor is almost clear with a light brown color and strong gassy odor. It contains combined cyanogen in many forms, the sulfocyanide is the predominating constituent. In a 1:240 dilution it gives the aquarium a pale yellow color with a faint gassy odor. The addition of the

waste produced no change in alkalinity or pH. Fish placed in this water were normal during 24 hours but when removed to S. T. water two died during the 24 hours in the S. T. water. This might be due to the fact that this acts as a slow poison and when once it affects them they cannot recover. While the fish were in this dilution the oxygen saturation dropped during the first hour 38 per cent and by the end of 24 hours it had dropped 60 per cent. This shows that the waste produces quite an oxygen demand.

This waste has a very high chlorine demand and when a 1:24,000 dilution is chlorinated so as to satisfy this demand and fish placed in it, they soon show almost the same physiological conditions as fish under the influence of cyanide. As a matter of fact, the activity resembled that produced by 0.8 p.p.m. NaCN, or 0.4 p.p.m. chlorinated sodium cyanide. At this dilution it is very toxic but the potency does not remain high very long. In less than 24 hours it has lost all its toxicity as shown by fish being again placed therein with no effect upon them. This liquor should not be permitted to enter a stream.

Rubber Reclaiming Plant Waste Liquor. The liquor is dark brown and opaque having an odor of old rubber. It also has an alkaline reaction. A 1:240 dilution in the aquarium produced a dirty yellow color with a distinct rubber odor. The alkalinity was raised 18 p.p.m. but no phenolphthalein alkalinity was present. During 1 hour in this water the fish showed no signs of distress except that they would not eat and when removed to S. T. water ate freely and all were perfectly normal the next day. A 1:2,400 dilution did not even affect the appetite of the fish during a contact period of 1 hour.

Saponified Grease from Animal Oil Plant. This waste liquor has the appearance of milk and when diluted 1:240 gives the aquarium a fragrant odor with a rather noticeable turbidity. The odor in the aquarium disappeared in about 24 hours with an oxygen saturation drop of about 40 per cent. Fish in this water for 5 days showed no signs of distress; however during this time the oxygen saturation never fell below 50 per cent.

Soap Mixture Waste. This waste liquor is brown and turbid. A 1:240 dilution gives the aquarium a slight turbidity and increases the alkalinity only 5 p.p.m. with practically no change in pH. The oxygen saturation during the first hour decreases 10 per cent so there is very little immediate demand caused by this waste. Fish in this water for 1 hour are perfectly normal and when transferred to S. T. water remain that way for another day.

Waste Liquor from sulfonation of animal oils. This liquor is a gray turbid oily mixture with an aromatic odor. A 1:240 dilution made the aquarium very turbid with oil spots on the surface. The aquarium then had a strong oily aromatic odor. The water was so turbid that fish could scarcely be seen 3 inches below the surface. During the first 15 minutes they would not eat and at the end of 1 hour showed no other effect than the lack of desire to eat. When removed to S. T. water they would not eat even after 3 hours but by the next day all ate freely. This waste produces a slight immediate oxygen demand in 1 hour and a slight increase in alkalinity. A 1:2,400 dilution showed no effect during 1 hour.

Sulfur Black Dye Waste. This is a black opaque liquor. When diluted 1:240 it gave the aquarium a dark color. Fish in this aquarium for 1 hour showed no visible effects and when removed to S. T. water they were still perfectly normal after 24 hours.

Synthetic Resin Plant Waste Liquor. This liquor comes from the autoclave after condensation. The waste was a reddish brown opaque liquor having a strong phenolic odor and in addition the odor of formaldehyde. It produced a very slight medicinal taste when diluted 1:25,000,000 and chlorinated. Only the higher dilution was tried upon fish because from experience with formalin it was found to be very toxic. The 1:2,400 dilution gives the aquarium a strong odor of the original waste. After 5 minutes contact with this the fish were darting around in every direction and showed some of the antics of fish treated with cyanide but there was no eye dilation. When removed to S. T. water the recovery was very slow; by the next day all were normal. This waste in the 1:2,400 dilution did not produce any immediate demand. The waste even if it had not affected fish should not enter a stream because it is one of the most powerful taste producers known.

Wool Scouring Waste. This is a light brown opaque liquor with the odor of laundry waste and freshly slacked lime. A 1:240 dilution made the aquarium water so turbid that fish could not be seen 2 inches below the surface. The water then had a color similar to clay water and the phenolphthalein alkalinity of 16 p.p.m. The oxygen saturation during the first hour decreased 11 per cent. Fish placed in this water for 1 hour were continually poking their noses out of the water and ate only sparingly. Upon removal to S. T. water they ate freely and were still alive the next day. A 1:2,400 dilution produced no phenolphthalein alkalinity. Fish in the water for 1 hour were perfectly normal in every respect.

Nitrogenous Products

Nitrogenous products of an organic nature, some of which may be found in sewage, are continually undergoing a transformation to the more stable forms.

The concentration of the following chemicals used is many times that which may be expected in stream pollution unless the stream is an open sewer. It was not the intention to increase the dosage to the point where death might occur but rather to try a fixed value and make a few observations over a period of 24 hours. In a concentration of 1 grain per gallon, each of the following chemicals—albumin, creatine, emulsin, creatinine, gelatin, peptone, tryptophane and urea—produced no noticeable effects upon the fish during 24 hours' contact. During the 24 hours the fish were in contact with each chemical, the oxygen saturation (per cent) drop was recorded as follows: albumin 28; creatine 6; creatinine 32; emulsin 41; gelatin 57; peptone 58; tryptophane 53; and urea 2. The chlorine demand and oxygen consumed as measured by permanganate (standard method) were determined for each of the products when in a concentration of 1 grain per gallon and are shown in table 1.

Plant Principles

Under this title are numerous vegetable products. They could easily find their way into natural water courses. Only a few of the poisonous variety have been investigated especially those that have been used as fish poisons. A very important group of natural occurring vegetable substances and one rather wildly distributed in nature is that known as the glucosides, especially the cyanogenetic glucosides. In this group are vegetable substances that contain nitrogen in a form that is potentially cyanide, for when acted upon by the proper substances, hydrocyanic acid is produced or its salts. They are thus called because of the fact, that not only cyanide is produced but another product of the reaction is sugar or glucose. This is usually brought about in nature by a ferment or enzyme called emulsin. Those producing cyanide are not uncommon and have been responsible for the death of cattle all over the world.

Couch (14) made an investigation of plants that poisoned livestock. His work is well worth reading for it covers the subject from all angles. Recently Water Works Engineering (15) carried a brief anonymous comment concerning the poisoning of cows after drinking

water containing algae. There is no doubt in the writer's mind that this also was due to a cyanogenetic glucoside. A few of the plants that are cyanogenetic in character are black cherry, flax, milkweed, Johnson grass, white clover, peach blossoms, Sudan grass, *Acacia*, manna grass, young sorghum grass, Guinea grass, Indian corn or maize, Kafir corn, joint leaf rush, some varieties of butter cup, *Eucalyptus cladocalyx*, *Photinia lindl*, *Zieria laevigata*, *Molinia coerulea* Moench., *Melica*, *Gynerium*, *Glyceria aquatica* Wahlb., and arrow grass. In the case of arrow grass the active poison is principally in the leaves. A curious fact about these plants is, if the growth is interfered with, due to external forces such as bruising, frost or *drought*, the plants develop a much larger amount of the

TABLE 1

Chlorine Demand and Oxygen Consumed of Nitrogenous Products

	CHLORINE DEMAND	OXYGEN CONSUMED
	lb. per million gallons	*p.p.m.*
Albumin (egg)	3.5	3.4
Creatine	<0.5	0.8
Creatinine	1.0	2.0
Emulsin	<0.5	1.4
Gelatin	1.0	2.1
Peptone	2.5	3.7
l-Tryptophane	120*	25.7
Urea	<0.5	0.1

* Calculated for 1 grain per gallon from a determination made upon a concentration of 1 p.p.m.

cyanogenetic glucoside than would normally be found. Almy and Robinson (16) found that linseed meal (not the oil) is very toxic when fed to brook trout. Hydrolysis takes place in their digestive tract and HCN is formed, due to the presence of a cyanogenetic glucoside. It makes them blind, black in color and produces accelerated motion, then inactivity. Some of the cyanogenetic plants run very high in potential HCN, that is, a yield as high as 1 per cent (dry basis) was reported by Finnemore and Cooper (17). A common cyanogenetic glucoside is amygdalin, first obtained by Robiquet and Boutron in 1830.

Amygdalin ($C_{20}H_{27}NO_{11}$). The most common and very likely the first known cyanogenetic glucoside is amygdalin. It is a white

crystalline substance having 3 molecules of water of crystallization and readily soluble in cold water. Amygdalin is widely distributed in nature and contained in bitter almonds, leaves of the cherry-laurel, peach, cherry, apricot, quince, and plum kernels, other hard nut fruit, *Cotoneaster* and some other *Rosaceae*; also many vegetable fibres contain it such as stem-bark and roots of mountain ash. Just a little over 100 years ago Liebig and Wöhler in 1837 found that amygdalin was hydrolyzed to glucose, benzaldehyde (oil of bitter almonds) and HCN. The active agent producing this hydrolysis is an enzyme called emulsin.

$$C_{20}H_{27}NO_{11}\cdot 3H_2O = C_6H_5CHO + HCN + 2C_6H_{12}O_6 + H_2O$$

The hydrolysis is not an immediate reaction and requires a little time until hydrocyanic acid appears.

Kenyon (18) made a very extensive investigation of the digestive enzymes in fishes. With this information the present writer sought to investigate the hydrolysis of amygdalin by minnows, so as to show that the glucoside would not necessarily have to be accompanied by its enzyme in order for cyanide to be produced. If this be true, then the catastrophes in streams during the great drought years might have been a natural phenomenon and not one caused by some industrial waste, as so many sanitarians supposed.

Determining Small Quantities of Cyanide

Before proceeding with the experiments using amygdalin it was necessary to have a method for determining small quantities of cyanide that might be formed by the hydrolysis. Hinman suggested that the work of Lavialle and Varenne (19) be reviewed and furnished a summarized translation of their work which was very helpful. A study of their method was made and after many determinations it was found possible to use it quantitatively, with some care, so as to determine as little as 0.1 p.p.m. NaCN when using a 200 c.c. sample of water. In all the determinations 200 c.c. samples were used and there is no difficulty determining 0.5 p.p.m. NaCN when making up standards using NaCN and carrying along simultaneously with the sample.

A brief outline of the method adopted is: Use a 200 c.c. sample of water to which is added 5 c.c. of colorless ammonium sulfide, then boil in evaporating dish for about 5 minutes. Remove to a steam bath and evaporate until almost dry, liquid residue of about 2 c.c.;

add approximately 10 c.c. of distilled water and wash around several times in the dish. Then add 10 drops of concentrated HCl and immediately pour into an 80 c.c. (total volume) separatory funnel with no vaseline. Wash contents of dish 3 times into funnel, using a small volume of distilled water. Then add 20 c.c. of ether. Insert glass stopper and shake vigorously for 3–5 minutes. Then allow the two liquids to separate, and repeat shaking a second and third time. After the third shaking, allow the two liquids to separate and draw off the liquid below the ether into the original evaporating dish and drain the ether, containing the sulfocyanic acid, into a small evaporating dish. Wash the contents of original evaporating dish into separatory funnel with only one washing and minimum quantity of distilled water. Add 10 c.c. of ether and shake again for three 5-minute periods. Draw off the aqueous layer and add ether residue to the first ether residue. Repeat the just mentioned procedure using 10 c.c. of ether for third and final extraction.

All the ether residues, now being together, are evaporated at room temperature by natural evaporation until nearly all the ether is volatilized. Just before the last trace (by odor) of ether disappears, if dish has a rather flat bottom, place dish in a slightly tilted position so as to increase the depth of residue and as soon as no odor of ether is detectable (volume then about 1 c.c.) add in very small quantities (just what adheres to tip of very thin glass rod) ferric chloride reagent with stirring, avoiding too great an excess, until the red color reaches a maximum intensity. Keep in mind that sulfocyanic acid is volatile and small quantities can easily be lost unless the ferric chloride is added immediately upon disappearance of ether. A very small quantity of gold chloride should completely destroy this red color. Ferric meconate gives same red color but is not soluble in ether and neither is it decolorized by gold chloride. Very small quantities of ferric meconate may however be retained by the ether.

The ferric chloride reagent is 484 grams $FeCl_3 \cdot 6H_2O$ dissolved in distilled water containing 40 c.c. concentrated HCl and then diluted to 1 liter.

The gold chloride reagent is a 10 per cent solution.

Ether required is C. P. grade, anhydrous, distilled over sodium. Each can of ether should have a sulfocyanide test made upon it.

Ammonium sulfide is the C. P. (colorless) common reagent purchased from any chemical supply house.

Sodium cyanide is C. P. or analytical reagent quality. The stand-

ard solution is made by dissolving 0.1000 grams in a liter of boiled (then cooled) distilled water and its decomposition may be retarded by keeping at ice-box temperature.

In order to see if it is possible for minnows to decompose the amygdalin, a strong solution was first used (70 p.p.m.) which increased the total organic and ammonium nitrogen of the water only 1.1 p.p.m. Fish placed in this water were perfectly normal at the end of 6 hours, by the next morning all were floating and appeared dead, this having occurred during the night. Upon removal to S. T. water they never recovered, for when fish float it is usually too late. The aquarium water was slightly turbid and when placed in a closed flask had a cold-odor of faint bitter-almond oil. When heated it was very strong. Cyanide test upon this water gave a very decided positive test.

Knowing that cyanide was present, 4 more minnows were put into the aquarium and between 1 and 2 hours they all went through the same 'stunts' as recorded under the pure cyanide experiments and when removed to S. T. water all recovered. This aquarium water was now allowed to stand for 7 days without fish and the turbidity and bitter-almond oil odor disappeared. A cyanide test at this time showed only a trace to be present. A trace of cyanide is 0.1 p.p.m. or less, expressed as NaCN. Minnows placed in this water did not react so that practically all of the amygdalin must have been decomposed originally and now the cyanide was below the effective value.

Parallel with this experiment an aquarium, containing drinking water open to the air, was treated with amygdalin but no fish were added. The odor, turbidity, D. O. and cyanide were observed from time to time. No reduction in D. O. took place and neither turbidity nor color developed. The test for cyanide was negative at the end of the seventh day but on the eleventh day the cyanide test showed a trace and continued with that value for 3 weeks and by the end of the fourth week it was almost negative, for by the end of the fifth week no cyanide could be detected. It thus took about 40 days to entirely decompose amygdalin by water of drinking quality, in an open aquarium. At no time was the concentration of cyanide great enough to affect minnows. It is quite possible that if the unhydrolyzed amygdalin is high, the fish if introduced then would act upon it and produce sufficient cyanide to affect them.

The quantity of benzaldehyde which may be detected by odor

when added as benzaldehyde is much smaller than when it is formed by hydrolysis of amygdalin, in which case the biological forces are at work tending to simplify the whole organic system. As a matter of fact, the hydrolysis of 43 p.p.m. of amygdalin by fish does not produce an almond oil odor whereas the smallest quantity of benzaldehyde, when added as benzaldehyde, detectable by its odor is about 3 p.p.m. Thus a body of water could easily contain a lethal (to fish) amount of cyanide produced from amygdalin and the water would not have the odor of almond oil.

Giving an aquarium sufficient amygdalin to produce a concentration of 7 p.p.m. (about 0.7 p.p.m. NaCN at 100 per cent conversion), the increase, in total organic and ammonium nitrogen, was only 0.16 p.p.m. Fish placed in this water were normal during 4 hours, but by the next day 1 minnow was dead and one almost dead, the others being normal. This concentration produces 50 per cent mortality in about 24 hours. The water at this time still had 40 per cent oxygen saturation. The cyanide determination upon the aquarium showed 0.7 p.p.m. which is a close check upon the theoretical, at 100 per cent conversion, by fish at the end of 24 hours. The experiment was repeated using the same concentration of amygdalin (7 p.p.m.) and 4 minnows. None of them showed any abnormal conditions in 48 hours, but some sign of distress did develop between 48 and 72 hours, but no mortality during 4 days. In this case with the same concentration as before, the effect was not nearly so pronounced, but in biological assay work, results are not always in as close an agreement as one might desire.

Minnows placed in a concentration of 3.5 p.p.m. of amygdalin were not affected during 7 days. Using a concentration of 7 p.p.m. and baby carp (about the length of the minnows used in all experiments) no effect was noticed during 24 hours, and the cyanide determination showed only a trace. On the second day turbidity developed but the fish were not affected. During the third day all were affected just as if in contact with NaCN, one was in distress and upon removal to S. T. water recovered. At this time a determination of cyanide showed 0.7 p.p.m. as NaCN. By the fourth day, the 3 fish that were left in the aquarium were still normal. Undoubtedly the mortality would have been 25 per cent. Thus, carp as well as minnows are affected by this concentration and it is safe to say that 7 p.p.m. of amygdalin is close to the least concentration which affects these two varieties.

In nature the enzyme usually accompanies the cyanogenetic glucoside, so under favorable conditions, the glucoside may be hydrolyzed with the production of cyanide. Thus it seems impossible actually to detect the cyanide in a glucoside such as amygdalin, when in natural water, before hydrolysis. Upon hydrolysis, one of its products (HCN), when detected, certainly is evidence of the presence originally of the glucoside, provided of course, the stream does not contain cyanide as a trade-waste. Even if the enzyme accompanying amygdalin in nature is not present, the fish-life of a stream can readily decompose the amygdalin with the production of cyanide.

Amygdalin in water does not create a chlorine demand. Drinking-water containing 0.20 p.p.m. of free chlorine had amygdalin added to it so as to produce a concentration of 40 p.p.m. and a contact time of 24 hours was permitted. By this time the residual chlorine had

TABLE 2

Color Reactions Produced by Concentrated Sulfuric Acid

	COLOR OF MATERIAL AFTER CONTACT	COLOR OF SOLUTION
Amygdalin	Orchid	Purple
Picrotoxin	Yellow	Yellow
Ricin	White	Colorless
Rotenone	Reddish brown	Orange
Sodium cyanide	White	Colorless

dropped to 0.04 p.p.m. Now minnows were introduced and during 24 hours were perfectly normal but between 24 and 30 hours all were dead. So it is safe to conclude that chlorine does not destroy the amygdalin when in contact with it for 24 hours. Thus a considerable quantity of this substance could get into a water supply and be unnoticed except as it is changed to cyanide which is a rather slow reaction. Even then the cyanide thus produced is not what one would call a high chlorine demand substance, but as cited before the presence of chlorine and cyanide produced a very toxic medium for fish.

Qualitative Reaction for Amygdalin

In order to see if some qualitative test might be characteristic of amygdalin itself, several reagents were tried and concentrated sulfuric acid was found to be the most satisfactory. Placing several drops of concentrated sulfuric acid on a spot-plate and adding only

about 0.1 mg. of material, any change in color of the material was noted and then, if soluble, the color of the solution. Table 2 permits the differentiation between the various fish poisons of the vegetable type and sodium cyanide. The color change of amygdalin is very characteristic (white to orchid). Saponin produces a color similar to rotenone. Peptone, picrotoxin and tryptophane are alike in color, i.e., yellow. Albumin, emulsin, gelatin and conine hydrochloride maintain their original color and the solution is colorless. The crystalline nitrogenous substances, creatine, creatinine and urea also remain white and the solution colorless. When water containing amygdalin, rotenone and picrotoxin separately is evaporated to dryness and ignited, dense white fumes are given off in each case and the odor of each is not sufficiently characteristic to be of any value, each finally chars, then ignites and disappears.

Enzyme Activity

Fish were permitted to contact water, containing no amygdalin, for 24 hours. They were then removed and amygdalin added so as to produce a concentration of 7 p.p.m. The water was tested for cyanide 24 hours after adding the amygdalin and only a trace of cyanide was present. This indicates that the enzyme activity imparted to the water by the fish was not sufficient to hydrolyze the amygdalin during the first 24 hours. A determination 3 days later, on the same water, showed the presence of 0.5 p.p.m. as NaCN, thus hydrolysis was only retarded. In this case a longer contact period was necessary, undoubtedly due to the low concentration of the active agent left by the fish originally in the water.

After a portion of water had had fish in it for 4 days, the fish were removed and a concentration of 7 p.p.m. of amygdalin established in it. A cyanide determination 24 hours after adding the glucoside showed the presence of 0.7 p.p.m. of cyanide as NaCN—in this case the reaction is much faster than the one previous. At the end of 48 hours there was still a little cyanide present and by the end of 72 hours only a trace remained. Amygdalin to the extent of 7 p.p.m. was again added and in 24 hours only a trace of cyanide could be found. Thus, a water which was able to hydrolyze the glucoside the first time failed to do it again during the same length of contact time.

As in the previous work an enzyme active water was prepared by allowing 4 minnows to contact S. T. water (20 liters) for a period of

4 days. The effect of chlorine, boiling and alum coagulation respectively is recorded as follows.

The chlorine demand was satisfied, leaving a residual of 0.22 p.p.m. and during the next 24 hours this dropped to 0.03 p.p.m. Amygdalin was then introduced so as to produce a concentration of 7 p.p.m. and allowed to stand for 24 hours, at which time a cyanide determination showed the presence of 0.5 p.p.m. as NaCN. Another determination after allowing an additional 24 hours' contact showed the presence of 0.7 p.p.m. or the maximum capable of being developed. Apparently the chlorine retards the action of the enzyme or decreases it, so that a smaller quantity requires a longer time to effect complete hydrolysis of the glucoside. At least, chlorine did not completely inactivate the enzyme.

Water boiled for 15 minutes was then cooled to room temperature and amygdalin added. A test for cyanide after 24 hours showed none to be present, i.e., complete inactivation of the enzyme. The assumption that enzymes are proteins is in accord with the facts as known up to the present time.

An alum dosage of 1 grain per gallon caused floc formation in the water. A settling time of 24 hours was allowed. The uppermost supernatant liquid, which was now clear, was then siphoned off and amygdalin added to it so as to produce a concentration of 7 p.p.m. This was thoroughly mixed, allowing 24 hours' contact. A cyanide determination then showed 0.5 p.p.m. as NaCN and another test 24 hours later, again showed only 0.5 p.p.m. and still another determination 24 hours later or 72 hours after adding the amygdalin showed 0.5 p.p.m.

The data obtained relative to enzyme activity produced by fish in water would seem to indicate: 1. Amygdalin is hydrolyzed by the biological flora and/or a chemical constituent left by the fish in the water and the active agent—*emulsin*—is in turn rendered less potent or is entirely inactivated; 2. Potable water in an open aquarium, which never had fish in it, could hydrolyze the glucoside only very slowly, i.e., over a relatively long period of time, with the production of cyanide never great enough to affect fish; 3. Chlorine does not destroy the enzymic activity; 4. Boiling completely inactivated the enzymic activity created by fish; 5. Enzymic activity must be due to a substance which is not in true solution, i.e., in the colloidal state and which at least in water is not negatively charged; and 6. It is doubtful, if the substance causing enzymic activity could be entirely

removed by coagulation with the quantity of alum as ordinarily used for filter plant operation.

Chenopodium Oil. A complete account of the toxicity of this oil to fish was described by Schaetzle (20). He found it to be a rather toxic fish poison, as 5–10 p.p.m. for a period of contact between 24 and 48 hours killed fish.

Only a rather incomplete study was given to this substance by the author. One grain per gallon gave the aquarium a very strong odor of the oil, which in this dilution is pleasant and has a sweet taste when chlorinated. In 4 hours the fish were affected and would not eat and in 24 hours all were dead. There was very little decrease in the oxygen saturation.

Conine ($C_8H_{17}N$). Conine is a powerful narcotic obtained from poison-hemlock, especially the seeds. The drinking of an infusion of poison-hemlock was in ancient and medieval times the honorable and accepted method of producing death. Conine is one of the alkaloids not containing oxygen. It is a dark brown liquid and insoluble in water; the hydrochloride is a white crystalline salt and quite soluble. Conine hydrochloride dissolved in aquarium water to the extent of 1 grain per gallon showed no effects upon fish during 5 days contact. There was no appreciable decrease in oxygen saturation during 4 hours. A cyanide test at the end of 24 hours was negative.

Marihuana Leaves. Marihuana leaves were obtained from an authentic source and an infusion of them placed in the aquarium. No noticeable effects appeared in the fish during 24 hours.

Picrotoxin ($C_{45}H_{50}O_{19}$). This is the active constituent of fish berries, a berry of an East Indian vine and used by the natives to stupify fish to aid in their capture. It is also found in grains of cockle which is a plant or weed that grows among grain, also in roots of *Stephania*. The crystalline salt containing one molecule of water is white and is quite insoluble in cold water but slowly soluble in hot water. It was first dissolved in ethyl alcohol and the aquarium treated so as to produce a concentration of 7 p.p.m. In this concentration by the end of 4 hours the fish were doing 'stunts' similar to cyanide and quivered as if fidgety and could easily be handled. In 24 hours the mortality was 50 per cent. Those that were still alive became normal at the end of 48 hours and were even normal at the end of 5 days. There was no abnormal drop in oxygen saturation. The test for cyanide was negative. The water, when chlorinated, had a strong medicinal odor. In a concentration of 4 p.p.m. the

effects were similar to 7 p.p.m., in this case the mortality was only 25 per cent. Fish affected by picrotoxin and transferred to S. T. water never recovered, which is quite different from the way cyanide affects them.

To drinking-water containing 0.20 p.p.m. of free chlorine, picrotoxin was added to produce a concentration of 7 p.p.m.; a contact time of 24 hours was permitted. By this time the residual chlorine had dropped to 0.08 p.p.m. Then minnows were introduced and by the ninth hour were starting to lose their equilibrium, and by the twentieth hour one was dead and another losing its balance. This one was transferred to S. T. water and never recovered. The mortality was 50 per cent which is a perfect check upon the same concentration of picrotoxin when in chlorine-free water. It is evident, a contact time of 24 hours between this plant principle and chlorine is not sufficient to destroy the toxicity of picrotoxin.

Ricin (toxalbumin). Ricin is a white amorphous powder, soluble in water and found in the castor-oil plant. Erb (21) states that the poisonous principle is located in the kernel of the seeds or beans and not in the coverings and three beans were fatal to an adult male.

Ricin is one of the toxalbumins and contains about 16 per cent nitrogen. Its composition is not definitely known. It is said to contain cystine, arginine, glutamic acid, tryptophane, tyrosine and no phosphorus. The fact that the minimal lethal dose by mouth is many times as great as by injection, under the skin or intravenously, indicates either that much of the toxin is destroyed in the gastro-intestinal tract or only a small part is absorbed. The toxalbumins are quite poisonous even when taken orally for they cause gastro-intestinal irritation with bloody stools.

When a concentration of 1 grain per gallon is established in the aquarium no characteristic odor is created even when a portion is chlorinated. Fish placed in this concentration were perfectly normal until about the tenth hour when they would not eat. By the twentieth hour all were rather sick looking and in 24 hours 75 per cent were wobbly and all were removed to S. T. water but only 1 recovered. The drop in oxygen saturation during the 24 hours was only normal for the water containing fish without any chemicals. The death-point concentration for 24 hours' contact was not determined as was done with other substances.

Ricin affects them a little differently from other poisons, as herein reported, in that the fish would survive the 24 hours' contact but

when transferred to S. T. water would die during the next 24 hours. It seems to poison them in such a way that it permanently affects them and is not easily thrown off. With 6 p.p.m. in the aquarium water their condition at the end of 24 hours' contact was not distressing but when removed to S. T. water only 50 per cent survived during the next 24 hours. This concentration might be considered the 50 per cent mortality value. Lower concentrations were tried without any effect being produced upon the fish even when transferred to S. T. water.

As ricin was found to have a chlorine demand, it became necessary to see if any change in toxicity was produced when water containing ricin was chlorinated to 0.20 p.p.m. Doing this, it was found that the toxicity was entirely removed, for fish placed in such water were normal during 24 hours and even when removed to S. T. water, were still alive for another day.

In order to see if the toxicity would return, the water in which ricin was detoxified by chlorine then had fish placed in it for a duration of 24 hours. This set of fish was removed and a second set of fish was in turn left in it for 24 hours. These fish did not show any effect during 24 hours' contact and when removed to S. T. water were still alive for another day. From this it is safe to conclude there is no restoration of the toxicity after the chlorine has disappeared and neither does the biological flora during 48 hours return its toxicity. It is interesting to note that Avery and Moreland (22) have shown by skin tests with rabbits that after the plant toxin, ricin, was detoxified by means of iodine, it could again become toxic by the use of sodium thiosulfate and is immunologically identical with that of the original sample.

Rotenone ($C_{23}H_{22}O_6$). Rotenone is one of the active constituents of Derris root sometimes called Cube, a Peruvian word, and is found in the Malay Archipelago, South America and in a weed common to the eastern half of the United States. This weed is called the devil's shoestring, a member of the pea family somewhat resembling the cow pea, which blooms in June and July with small yellow purple flowers. In the upper Amazon country it is called Barbasco. The rotenone content of these plants runs anywhere from a few tenths of 1 per cent to 10–15 per cent. A very comprehensive dissertation on rotenone and its relative products has been compiled by Roark (23) from 1919 to 1938.

Rotenone is a very insoluble salt and during this work the solu-

bility was found to be 0.9 p.p.m. at 22°C. It was necessary to dissolve it in acetone and then this solution was added to the aquarium water. A concentration of 0.03 p.p.m. after 1.5 hours' contact affected the fish and in 24 hours produced 100 per cent mortality; 0.02 p.p.m. in 5 hours affected them only to the extent of spoiling their appetite and by the end of 24 hours they were perfectly normal and ate freely. The concentration producing 50 per cent mortality is obviously between 0.02 and 0.03 p.p.m. This is a very toxic fish poison and for years has been used by the natives to catch fish, for it makes them come to the surface, and by clubbing the fish, their food supply was obtained in this manner. Its action is similar to picrotoxin only much more potent.

Rotenone produces a slight reddening of the body at the side fins. The fish do not recover as quickly as when treated with cyanide. Neither does it accelerate them quite as much as cyanide. When fish are under the influence of cyanide they usually seek the bottom only after much initial activity, with loss of equilibrium, and are then easily picked up. As a rule they do not come up again except when near death and then slowly rise to the surface. Even at this time if transferred to other water they may recover. With rotenone, after going to the bottom, they still have plenty of energy and are not easily handled. After several trips to the top they are easily picked up and it is for this reason that the natives using rotenone as a fish poison are described as clubbing them when they reach the surface. A cyanide test upon water containing rotenone was entirely negative.

Since this substance is such a potent fish poison and grows in the United States and the quantity required to kill fish is so small, with our present knowledge of rotenone it would be somewhat difficult to detect its presence directly in water by chemical laboratory reagents. Jones and Smith (24) have modified the Durham color test and record detection of 0.1 mg. of rotenone. There are other plant materials related to rotenone occurring with it that give the same color. Picrotoxin, ricin, chenopodium oil, amygdalin, emulsin, saponin, conine hydrochloride, tannic acid and sodium cyanide do not give a color with this modified test. Goodhue (25) improved on the Gross and Smith color test so as to make it still more sensitive whereby as little as 0.005 mg. per c.c. may be detected. Even in this low concentration the rotenone content is many times that necessary to affect fish. A few brief tests showed that this improved test

did not react with cyanide, amygdalin, emulsin, picrotoxin, ricin, conine, saponin, tannic acid, and chenopodium oil. Chenopodium oil produces a red color after standing an hour or so but the contents of the tube are not clear, due to the emulsion-like medium. The oily layer which separates on top has concentrated in it most of the color. The red color reaction is much more desirable for quantitative work because the clear red color is rather permanent, whereas, the reaction producing a blue color is only transient. The rose-red color does not develop when rotenone is dissolved in carbon tetrachloride. The blue color reaction of the modified Durham test may be obtained when rotenone is dissolved in carbon tetrachloride, as the entire liquid above the carbon tetrachloride turns blue for a short time.

To laboratory tap-water containing 0.20 p.p.m. of free chlorine rotenone was added so as to produce a concentration of 1 p.p.m. and a contact of 24 hours was permitted at which time the residual chlorine was 0 p.p.m. Minnows were then placed in this water and in 15 minutes all were doing 'stunts' and soon lost their balance and in ½ hour were removed to S. T. water and never recovered; hence rotenone was not destroyed by chlorine in a concentration that is usual practice in water works operation.

Saponin ($C_{32}H_{54}O_{18}$). Saponin is one of the glucosides and may be obtained from hay, alfalfa and other vegetable material. It is a white amorphous powder, readily soluble in cold water and if the water is agitated a froth is easily produced. A concentration of 1 grain per gallon gives the aquarium an aromatic woody odor and when a portion of the water is chlorinated the taste is slightly medicinal. This substance did not produce any abnormal decrease in oxygen saturation during 24 hours and all the fish were perfectly normal. A cyanide test upon this water was entirely negative. Ellis (1) found, using goldfish, that 10 p.p.m. affected them in several hours and 100 p.p.m. killed them in 7–24 hours.

Tannic Acid ($C_{14}H_{10}O_9$). Tannic acid is readily soluble in water and when added to the aquarium so as to produce a concentration of 1 grain per gallon, it imparts to the water when a portion is chlorinated, a cold odor of a sweetish character. This concentration produced only 1 p.p.m. decrease in alkalinity. The oxygen saturation decreased during 1 hour by 23 per cent. By the end of 24 hours it had decreased 59 per cent but the water still had in it sufficient oxygen to be well above the safe limit for fish. The water during this time became yellow in color and by the end of 24 hours had changed

TABLE 3

Chlorine Demand and Oxygen Consumed of Substances in Concentration Indicated that are not Fish Poisons

	CHLORINE DEMAND	OXYGEN CONSUMED
	lb. per million gallons	*p.p.m.*
Acetone (1:20,000)	<0.5	0.0
Benzaldehyde (1 gr./gal.)	<0.5	6.3
Dextrose (1 gr./gal.)	<0.5	10.2
Saponin (1 gr./gal.)	<0.5	8.1
Tannic acid (1 p.p.m.)	6.5	1.1

TABLE 4

Solubilities of Chemical Substances

	DISTILLED WATER	ETHYL ALCOHOL 190 PROOF	ACETONE	CARBON TETRACHLORIDE	CHLOROFORM	ETHER	ETHYL ACETATE
Amygdalin	S	I, s-h	I	I	I	I	I
Chenopodium oil	I	S	S	S	S	S	S
Picrotoxin	I, s-h	S	S	I	S, sl	I	S
Ricin	S	I	I	I	I	I	I
Rotenone	I	S	S	S	S	S	S
Sodium cyanide	S	S, p	I	I	I	I	I
Conine HCl	S	S	I	I	S	I	I
Saponin	S	I	I	I	I	I	I
Tannic acid	S	S	S	I	I	I	I
Albumin (egg)*	I	I	I	I	I	I	I
Creatine	S	I	I	I	I	I	I
Creatinine	S	I, sl-h	I	I	I	I	I
Emulsin*	I	I	I	I	I	I	I
Gelatin*	I, s-h	I	I	I	I	I	I
Peptone	S	I	I	I	I	I	I
l-Tryptophane	I, s-h	I	I	I	I	I	I
Urea	S	S	I	I	I	I	I

s-h, soluble when heated. p, partly. sl, slowly. sl-h, slowly when heated.

* These substances due to their colloidal nature form sols of the suspensoid type and are not taken up by water or other solvents as are the crystalloids.

to black, due to a small quantity of iron present in the water. The only effect produced upon the fish was that they would not eat at the end of 1 hour and by the end of 24 hours ate only sparingly. There was no mortality. Tannic acid is one of the vegetable principles which has a rather high chlorine demand, while those that are fish poisons show practically no affinity for chlorine with the exception of ricin and even its demand is rather low. In table 3 are shown a few substances that are not fish poisons in the concentration indicated and with the exception of tannic acid have practically no chlorine demand. It is to be noted that when the proportionate chemicals produced by the hydrolysis of 30 p.p.m. of amygdalin are added separately to the same aquarium containing S. T. water and

TABLE 5

Chlorine Demand and Oxygen Consumed of Fish Poisons in Concentration Indicated

	CHLORINE DEMAND	OXYGEN CONSUMED
	lb. per million gallons	*p.p.m.*
Amygdalin (40 p.p.m.)	<0.5	4.9
Picrotoxin (1 gr./gal.)	<0.5	3.9
Potassium sulfocyanide* (1 p.p.m.)	20	0.5
Ricin (1 gr./gal.)	2.5	2.5
Rotenone (1 p.p.m.)	<0.5	1.3
Sodium cyanide (1 p.p.m.)	5.5	0.1

* Potassium sulfocyanide is not a fish poison. It is included in this table because when chlorinated it produces a poison of rather high toxicity to fish.

the chlorine demand and oxygen consumed determined, the values of 15 lb. and 16.5 p.p.m. were actually obtained respectively. These check rather closely (less than 10 per cent) the sum of the individual values shown in table 3 when proportionately calculated. Apparently these values may be considered additive from a mathematical standpoint.

The solubility of chemicals from a qualitative standpoint is always desirable to have tabulated, particularly when one is interested in their extraction and separation, and is presented in table 4. In this table which is intended for qualitative purposes only, about 5 mg. of solid were treated with 2 c.c. of the solvent and only what the eye could detect in the way of a change, was recorded. Distilled

water and alcohol were the only solvents used in the cold and hot, and hot refers to boiling temperature.

The poisons producing similar physiological symptoms are amygdalin, picrotoxin, rotenone, sodium cyanide and sodium cyanide solution chlorinated. Potassium sulfocyanide solution after having the chlorine demand satisfied produces a medium quite similar to cyanide both as to physiological activity and toxicity. In table 5 are shown chlorine demand and oxygen consumed values for the fish poisons.

Relative Toxicity

Toxicity is usually expressed as 'toxicity index' using phenol as the reference chemical or datum line and thus designating the other

TABLE 6

Concentration in p.p.m. Producing 50 per cent Mortality in 24 hours

Amygdalin	7
Copper sulfate (bluestone)	1.3
Picrotoxin	7
Ricin	6
Rotenone	0.025
Sodium cyanide	0.75
Sodium cyanide (chlorinated)	1/2 NaCN

substances as having a certain phenol coefficient. Phenol should not be permitted to enter a water supply, not due to its toxicity which is very low but because of its strong taste-producing power when the water is chlorinated. In the field of water treatment, as far as fish mortality is concerned, it would appear to be more logical to use the fresh-water minnow and compare the toxicity of chemicals using $CuSO_4 \cdot 5H_2O$, as the reference chemical. Taking this as unity, the relative toxicities as shown in table 6 are approximately: amygdalin, picrotoxin and ricin, $\frac{1}{5}$ the toxicity; sodium cyanide chlorinated *loc. cit.*, 3; sodium cyanide itself, 1.5; rotenone, the most toxic of the fish poisons, about 50 times as toxic as copper sulfate.

Gersdorff (26) reports the relative toxicity, using goldfish, of rotenone, potassium cyanide and phenol as 4, 0.16 and 0.0008 units respectively.

River Environment

One familar with river patrol work cannot help but notice, at times, many small worms in river-bottom mud and it was thought the eating of these worms, might be detrimental to fish life. Also if water were permitted to concentrate by natural evaporation in the presence of river-bottom mud something might be extracted from the mud that would affect them.

Worms. Several small worms collected from river-bottom mud were placed in an aquarium containing minnows. Immediately the fish ate the worms until their appetite was satisfied and left the rest of them untouched for another feast. In one hour 1 large fish was down on the bottom and even though removed to S. T. water did not recover. One of the other large minnows was darting around near the bottom with quick jerks. This activity continued for 2 hours and by the next day all activity seemed to be normal and even after 48 hours, at which time all the worms were consumed, the fish were still normal. Why the one died is still unknown and it is assumed that river-bottom worms are not detrimental to fish life, especially large fish. In this case the minnows are not much longer than some of the worms whereas the so-called large fish in a stream are from 10 to 20 inches in length.

River-bottom Mud. River-bottom mud collected during the spring of the year was placed in an aquarium and S. T. water siphoned into it slowly so as not to disturb the mud. After standing for 72 hours to bring about equilibrium between the water and mud, the oxygen saturation was found to be 12 per cent even though the water run into the aquarium originally had a 100 per cent saturation. At this time, before putting in the fish, a leech 3 inches long was observed, 6 to 8 snails and the bottom mud contained thousands of white worms about the size of a pin. Fish placed in this aquarium immediately started to eat the worms and nothing of an unusual character developed. From time to time, make-up water was added. The nitrites in the water rose from 0 to 3.2 p.p.m. in about 2 weeks and then gradually decreased until 0.002 p.p.m. was reached in about 6 weeks. During this time the oxygen saturation slowly rose until it reached an equilibrium point at 55 per cent saturation. The fish showed no abnormal conditions during all this time and no food was given them. It was decided to repeat this experiment using mud collected during the fall season and allowing the water to concentrate by natural evaporation.

Mud was collected in the latter part of September and used as in the former work, except no make-up water was added during the entire time, which in this case extended over a period of 4 months. The depth of water above the mud decreased from 7 inches to 1 inch during this time and there was scarcely enough water to cover the fish. During the first month no fish died. At this time a cyanide determination was entirely negative. After the first month 50 per cent died and looked emaciated due to the lack of food. At the end of 4 months with only 1 inch of water covering them, 50 per cent of the fish were still alive. Those that died did not go through any antics, but just seemed to gradually succumb for want of food. The reason for not feeding them, was to force the fish to feed upon whatever they could find in the mud.

River Inspections

As mentioned in the beginning of this paper, the work was conducted in order to arrive at a probable cause of the fish catastrophe in the Schuylkill River during the drought years. Other streams throughout the country during drought years showed similar phenomena as reported by Tisdale (27). The activity was always in pools formed back of dams over which ran very little water during the low-water period. These pools were subject to natural evaporation and thereby concentrating whatever constituents were in the water. About 2 days before the fish became active, the pool would take on a smoky appearance and gas liberation was quite noticeable but no odor. Many river-bottom worms could be seen. This smoky appearance is called by Fitch et al. (28) "water bloom" and is defined by them as the phenomenon when the waters of a lake suddenly become turbid from the growth of blue-green algae.

Hundreds of fish in these pools showed activity similar to that produced by cyanide and when the fish were removed to water below the dam, they recovered in a short time. The fish during the catastrophe, besides going through all kinds of antics, were noticed to vomit a slime and some of this material was examined under the microscope and found to be amorphous in character with some *Monas* and a little *Spirogyra*. Dr. Van Deusen, who is director of the Philadelphia Aquarium, looked at this slime and said it appeared to be excrementitious matter. One of the carp about 10 inches long was opened up and its organs examined. The organs were not ruptured although the air-sac along the back bone was very much

distended, the membrane being very thin in one portion. Gills appeared normal. Blood was reddish in color. The fish had a fresh odor, indicating that it had died only recently. It did not appear emaciated and fat was present inside of the fish. Bassingdale et al. (29) noted that the gills of trout were a brighter red than normal when they died from cyanide poisoning while phenolic compounds made the gills darker.

Fish tests upon the water when brought to the laboratory from the pool showing the most activity produced the same physiological conditions in an aquarium containing minnows, perch, sunfish, carp and catfish of a small variety. A complete sanitary analysis of the water was made and in addition some special tests were performed and only the outstanding results are presented. The presence of a cyanogenetic glucoside would only raise the oxygen consumed and total nitrogen a slight amount. These high values would not in themselves lead one to suspect a toxic substance present. After all, a sanitary chemical analysis is of little value in an investigation of this kind. A microscopic examination revealed no organisms present but a little amorphous matter was found. The cold odor was very strongly woody. Then a portion of the water was acidulated with sulfuric acid and heated and no odor of hydrogen sulfide was produced. Dissolved oxygen determinations throughout the pool of both top and bottom water showed saturation values around 64 per cent (not over 5 per cent variation either way) with practically no variations from top to bottom. The carbon dioxide determinations were approximately 4 p.p.m. A test for sulfocyanide (CNS) showed it to be absent. Determination of cyanide (CN) showed it to be between the 1 and 5 p.p.m. standards of NaCN and by observation the value was nearer the high standard. Below the dam the cyanide test was negative, and a mile above the dam it was also negative.

The approximate capacity of this pool figured at its minimum would indicate, at a cyanide content of the water equal to 3 p.p.m., the total cyanide as NaCN to be 2 tons and could easily be twice that figure. The pollution of a stream by cyanide waste is not an unheard of happening, for Wieters (30) reports cyanide getting into a small stream in Iowa from a plating plant. An inspection of the pool and the industries above it on the Schuylkill River where the fish catastrophe occurred showed that *no one nor combination of industries* could discharge 2 tons of NaCN, and repeat this again the following year, in each case during the fall season. This condition

has not, to the writer's knowledge, occurred before or since these two drought years. Any cyanide from the industries, other than those doing electro-plating, would be accompanied by a much greater quantity of sulfocyanide and last but not least a strong medicinal taste when chlorinated. As the pool was gassing at the time of the fish catastrophe there is no doubt but that organic decomposition of the bottom mud was taking place, but the odor over this body of water was not that of sulfuretted hydrogen and neither was the slightest trace of the odor of oil of bitter-almonds detectable, so any cyanide present was in solution.

Discussion

The formation of cyanide in the human body, from ordinary articles of diet, is said by some investigators to be impossible due to the thermodynamics of the reaction. Outside of the human body, surely a higher temperature is necessary to combine the elements, while within the body these virtual 'power-houses' *enzymes* could easily do this. Others believe that for sulfocyanide to appear in the urine and saliva, the cyanide ion must be formed first and then the immediate detoxication of the cyanide ion take place in the liver by coupling with bivalent sulfur derived from an *amino* acid such as *cystine*.

The breaking-down of complex protein material by normal digestive processes does not form the cyanide ion. The nitrogen goes rather to *amino* acids such as *alanine*, *glycine*, *histidine*, *tryptophane*, and *cystine*, et al. and by katabolic processes the nitrogen of *amino* acids is converted into urea, uric acid and to a lesser extent into other nitrogenous organic compounds like *creatine*, *creatinine* and into ammonium salts.

The excrement from humans as far as its organic nitrogen content is concerned consists of albuminoid material derived from protein of bacterial cells, undigested or partly digested protein in the feces, and nitrogenous organic compounds including the *ptomaines* and the *leucoamines* that yield ammonia by hot alkaline permanganate digestion. Nowhere in the literature has been (as far as the writer could find) recorded the finding of the cyanide ion in sewage or polluted waters. This is not surprising, for sewage is always alkaline and contains sulfides. Any cyanide ions formed would immediately be converted to sulfocyanide. It is interesting to note that, at about the turn of the Century, Hamtzsch and Plimmer (31) discussed the

oxidation of albumins with the formation of prussic acid and that the *amino* group play only a small part in the formation of HCN, but in their work strong oxidizing agents were used. Another note of interest in the literature which recently appeared is that of Hall (32) showing that strong oxidizing agents do convert thiocyanate to cyanide but that nitrogen is more likely to appear as ammonium ion when selenium compounds are acted upon by alkaline thiocyanate. The present writer showed (*loc. cit.*) in very dilute solution by means of biological assays and chemical tests that chlorine (free) oxidized the sulfur in the thiocyanate to sulfate thereby leaving the solution very toxic to fish due to presence of the cyanide ion.

It might be possible under abnormal conditions as *drought*, with a high concentration of all the constituents (organic and inorganic) in water at this time, that the biological and chemical processes do not act 'true to form' and cyanide appears as one of the products of decomposition. As yet there is nothing to support this possibility other than the findings of Gettler and Baine (33) that the putrefaction of human tissue produces a very small quantity of cyanide and at the same time some sulfides.

The decomposition of organic matter in a pool back of a dam where undoubtedly sulfur compounds are available (organic and inorganic) should be expected to produce some form of sulfides which at least could be detected by either their familiar odor in the faintly alkaline medium like water or surely upon acidulation of the water, especially if warmed. Then also, if sulfides are present (or at least sulfur) one would again expect any cyanide produced to be converted into sulfocyanide. This was not the case in our river, for fortunately sulfocyanide was not found in this water and the water had neither a putrid nor sulfide odor at this time.

Cyanogenetic glucosides are not suspected to be present in a water until some physical evidence appears, as that produced upon fish, and then the glucoside is no longer present as such and all that remains to be found in the way of chemicl evidence is the cyanide produced from it. This *modus operandi* is not far different from what is observed in the radioactivity of the elements where, because one element is found, the parent substance from which it came by radioactive decomposition must have been originally present even though it is no longer present at the time its degradation product is found. There is only one bit of missing evidence and that is the detection of the glucoside as such in water. This is not readily done, especially

in the high dilution in which it might appear in natural water courses and with the other organic products that would be present along with the glucoside at such a time as drought periods. Rimington (34) proposed a method for the direct detection of hydrocyanic acid in cyanogenetic glucosides by means of *emulsin* and picrate paper. Here again, it is not a direct identification of the glucoside as such, nor will this reaction be detectable in very dilute solutions, as in a natural water supply.

Summary

This physiological phenomenon of mass destruction of fish was seen by the writer only during the 2 drought years 1930 and 1931 and occurred within the same 8 weeks of each year.

At the time of this phenomenon no industry could be found that could possibly put the quantity of cyanide (CN) into the stream necessary to create this condition.

During the following 8 years it has been impossible for the River Patrol or anyone else to obtain any inkling as to an industry which had discharged cyanide (CN) into the stream.

Industrial wastes containing sulfocyanide when permitted to enter a stream cause the stream to have a very high chlorine demand and if this water is chlorinated to the point where the demand is satisfied, cyanide is produced. Hence this water becomes very toxic to fish.

Industrial wastes containing cyanide (CN) become very potent fish poisons especially if chlorinated.

Industrial wastes are not always the cause of fish mortality in streams, for *nature* herself probably has many toxic substances, as yet unknown, which are inimical to fish life.

The oxygen saturation of the river water and high nitrites were not in themselves a cause of this phenomenon, and neither were sulfides nor the gases, hydrogen sulfide and methane.

The chloride content of the river water never exceeded 22 p.p.m. and Ellis (*loc. cit.*) reported close to 10,000 p.p.m. as NaCl are necessary to produce death of fish.

Cyanide was found in the river water to the extent necessary to affect fish and would eventually have killed them.

Sodium cyanide in the same concentration will produce the identical effects in fish in an aquarium as noted in the stream. Sodium cyanide affected large as well as small fish in an aquarium.

Chlorine increases the toxicity of cyanide.

Drinking-water containing chlorine and cyanide and allowed to stand for a day is still toxic to fish.

Amygdalin is a cyanogenetic glucoside, very widely distributed in nature and readily soluble in water.

Amygdalin only hydrolyzes very slowly in drinking-water and the time required for its complete decomposition is many days. During all this time the cyanide produced is just barely detectable.

Amygdalin in drinking-water, to which fish are added, is hydrolyzed with the production of all its potential cyanide in a relatively short time.

Amygdalin upon hydrolysis produces the same physiological symptoms in fish as sodium cyanide.

Amygdalin (40 p.p.m.) has no chlorine demand and a very low oxygen consumption as measured by permanganate.

Drinking-water, containing chlorine and amygdalin and allowed to stand for a day, is still capable of producing the physiological phenomenon in fish after they have been in the water a while.

Amygdalin gives a color reaction in concentrated sulfuric acid which is not shared by other fish poisons.

Minnows contain the *enzyme* necessary to hydrolyze amygdalin.

Minnows impart *enzyme activity* to water, which may be measured by the hydrolysis of amygdalin.

Enzyme activity was present in the river water toward the end of drought to the extent necessary to hydrolyze a cyanogenetic glucoside.

The detection of *enzyme activity* in water should be included in the list of tests to be made upon water, especially during the times of drought.

Chlorine does not destroy the enzymic activity, while filter alum decreases it about 30 per cent and boiling causes complete inactivation.

Some poisons are harmful to both humans and fish, while *conine*, one of the most toxic to man *per os*, apparently does not affect fish. On the other hand, the most toxic fish poison—*rotenone*—is now pretty generally accepted to be non-toxic to man, as shown by Ambrose and Haag (35) especially in the quantities found on sprayed vegetables and fruits.

The water which caused the fish catastrophe in our river lost its toxicity before it reached our raw water reservoirs supplying the filter plants, because these reservoirs contain many fish of all sizes and no fish catastrophe occurred in these reservoirs.

An outstanding public health feature, during the fish catastrophes at Philadelphia, is the fact that those using the city water showed no ill effects at the time or shortly thereafter.

The author wishes to express his sincere appreciation to Seth M. Van Loan, Chief Engineer of the Water Bureau, for the interest shown in this work and to the members of the Laboratory Staff who were so patient and gave of their time so this work could be brought to a successful conclusion. Our river patrol consisting of Messrs. Crawford and Kinslow was indispensable in carrying on this work. Without their aid it would have been almost impossible to solve this problem satisfactorily.

Dr. Robert O. Van Deusen, Director of the Philadelphia Aquarium, gave of his time and also furnished practically all the fish necessary to carry on this work. He also gave free use of whatever equipment he had at the aquarium.

Very early in this study Dr. Carl L. Hubbs, Director, Institute of Fisheries Research of the University of Michigan, furnished the author with a typewritten paper containing much useful information as to the effect of cyanide upon various species of fish. In another personal communication Dr. Everett F. Davis, National Institute of Health, Washington, D. C., suggested that the plant principle *hydrojuglone*, contained in root bark and hulls of unripe walnuts, was responsible for killing fish when sacs containing them were dragged through a fish pond.

Dr. Jack J. Hinman, Jr., Associate Professor of Sanitation, University of Iowa, Iowa City, gave the author a chemical method for the determination of cyanide which was a key to the whole situation.

Appreciation is due the author's faithful counsellor Dr. Joseph S. Hepburn, Associate Professor of Chemistry, Hahnemann Medical College, Philadelphia, Pa., who has been a constant source of inspiration in all this work.

It would be a source of gratification to the author, if this report furnished some other investigator with a single idea which might help him solve a related problem.

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W.P.A. Projects in New York City

By Patrick Quilty

PRIOR to the establishment of the W.P.A. on August 1, 1935, several water mains and other projects had been carried on for the Department of Water Supply, Gas and Electricity by certain work relief agencies previously functioning, these being: first, the Works Division of the Emergency Relief Bureau; second, the Temporary Emergency Relief Administration; and finally, the Civil Works Administration.

The W.P.A. took over and greatly enlarged the scope of the activities of these former agencies. New work project proposals covering all five boroughs were set up and transmitted to the Washington authorities for approval and allotment of funds. These projects may be broadly classified under four main groups, these being:

1. Installation of water mains and appurtenances for the extension and improvement of the distribution system.

2. A special project for reconditioning the interior of a 72-inch steel water main, some 21 miles in length, from Ridgewood pumping station in Brooklyn, along Sunrise Highway, through Queens and Nassau Counties to the Suffolk County Line.

3. Alterations, repair and extensions of department buildings, including in some instances the erection of new buildings.

4. Non-construction, or so-called "white collar" projects, involving various surveys and studies, through which certain data were obtained, believed to be of value for the proper operation and maintenance of the system.

Installation of water mains consisted of hauling and laying cast-iron water mains, 6 to 20 inches in diameter, including the valves, hydrants and appurtenances thereon, all joints being bell and spigot, and made with poured lead, properly caulked. A small amount of

A paper presented at the New York Section meeting at New York City, December 29, 1938, by Patrick Quilty, Acting Chief Engineer, Bureau of Water Supply, Dept. Water Supply, Gas and Electricity, New York City.

2-inch galvanized iron pipe, laid with threaded couplings, was also installed, to serve as temporary mains in ungraded streets.

During the 38 months between August 1, 1935 and September 30, 1938 there were laid 1,276,000 feet, or about 242 miles of mains, in all boroughs. (See table 1.) The project has been gradually enlarged since its inception, and at the present time there are being laid about 46,000 feet, or 9 miles per month, the maximum rate of installation attained this summer being about 10 miles per month. The W.P.A. force employed has varied, but consists at present of about 3,200 men, of which 1,800 are common labor, divided into gangs of 40 to 50 men, this force being employed on water main projects

TABLE 1

Water Mains Installed by W.P.A. during 38 Months

SIZE	NO. OF LINEAL FEET	SIZE	NO. OF LINEAL FEET
inches		*inches*	
2	46,151	16	22,216
4	866	16 high pressure	1,456
6	52,542	20	44,105
8	690,842	20 high pressure	7
8 high pressure	180	24	496
10	2,577	30	451
12	413,643	36	51
12 high pressure	155		
Total			1,275,738

only. The total W.P.A. force employed on department projects is about 4,000.

At the present time the installation of trunk mains 30-inches and larger, which are of steel, is still effected by contract, since this work has not been undertaken by the W.P.A.

The superintendents in charge for the W.P.A. on this project include many men who formerly were contractors on water main work, and since said work is supervised and inspected in the field by the city's personnel it compares favorably with that hitherto executed by the contract system, as to quality and workmanship. The project is therefore one from which the city derives a substantial benefit, there being obtained through it a permanent addition to the water system, with a saving in the cost of labor.

During 1935 and 1936 the W.P.A. furnished not only the labor and

equipment, but also part of the materials, such as pipe, castings, valves, and hydrants, required for the work. Subsequently, during 1937 and 1938 the city was called upon to increase its contribution, and all of the pipe, castings, valves, hydrants, lead, and yarn, were furnished by the department.

For the 1938 program the city furnished all materials, including even those of minor nature, such as sand, cement, etc., and also about $300,000 required for the purchase and hire of equipment. This equipment had previously been hired, and to reduce the expense the city purchased at a cost of $175,000 some 60 motor vehicles, consisting of trucks, compressors, etc., which were turned over to the W.P.A. for use on the project.

The 1939 program calls for the installation of about 110 miles of mains from 2 to 20 inches in diameter, together with incidental appurtenances, and miscellaneous improvements to the system.

Interior of 72-inch Conduit Is Coated

A 72-inch pipe, which conveys water pumped into it from a number of well developments along its route, was laid about 34 years ago, and the lining, which was of a type not now in use, has deteriorated to a great extent. For the past $2\frac{1}{2}$ years a W.P.A. force of 75 to 110 men has been engaged on recoating the interior of this conduit. As shown in fig. 1, the work consists of cleaning and scraping the inside surface, by means of hand and power brushes, to the bare metal, applying a cold primer, and then a hot coal tar enamel hand-brushed on to a thickness of about $\frac{1}{16}$ inch. Access is attained through existing manholes and cuts made in the line, portable blowers and generators operated by gasoline engines being used for ventilation and lighting. About 11 miles of the pipe reconditioning has been completed, and the work is to continue during 1939 until the entire line is recoated.

The projects enumerated below provided facilities which the department greatly needed for the storage of vehicles and other equipment, and for repair company headquarters, machine shop, etc.

1. A four-story building at 60–62 West 133d Street, borough of Manhattan, was converted from a non-fireproof stable into a fireproof garage, for use by the North Manhattan Repair Company as a headquarters. The size of the building is 50 by 100 feet. The alteration involved the removal of all the interior, and substituting for it new fireproof construction. The territory covered by this repair company

FIG. 1. Scraping the Inside of a 72-inch Steel Main

extends from 86th Street north to the limit of the borough of Manhattan, from river to river. (See fig. 2.)

2. An extension was built to the existing garage and repair company headquarters in the Second Ward, borough of Queens. The size of this extension is 65 by 40 feet; it is one story in height; and the estimated cost is $24,000. Also a new 20 by 74 foot one-story auto repair shop has been constructed at a cost of about $12,000.

3. An extension has been made to the East Bronx garage and repair company headquarters at Zerega Avenue, borough of the Bronx.

FIG. 2. Fireproof Garage Built for the North Manhattan Repair Shop

The size of this extension is 60 by 43 feet, and it is one story in height. This work was carried on under certain difficulties, as the ground consists of fill unfit to sustain any loads.

4. A remodeling job has been done in a three story and basement stable, transferred to this department by the Department of Sanitation, located at Flushing Avenue, borough of Brooklyn. The size of the building, which is bounded by four streets and occupies a full block in area, is approximately 165 by 190 feet. The alteration involved is the construction of new ground and second stories, and new floor slabs for the third story. In the original building the

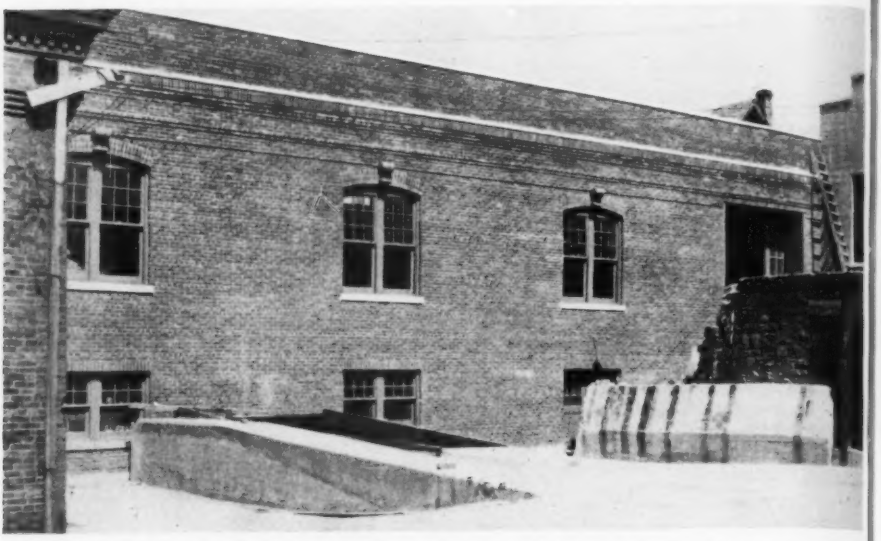

FIG. 3. An Extension Built at West New Brighton, Staten Island

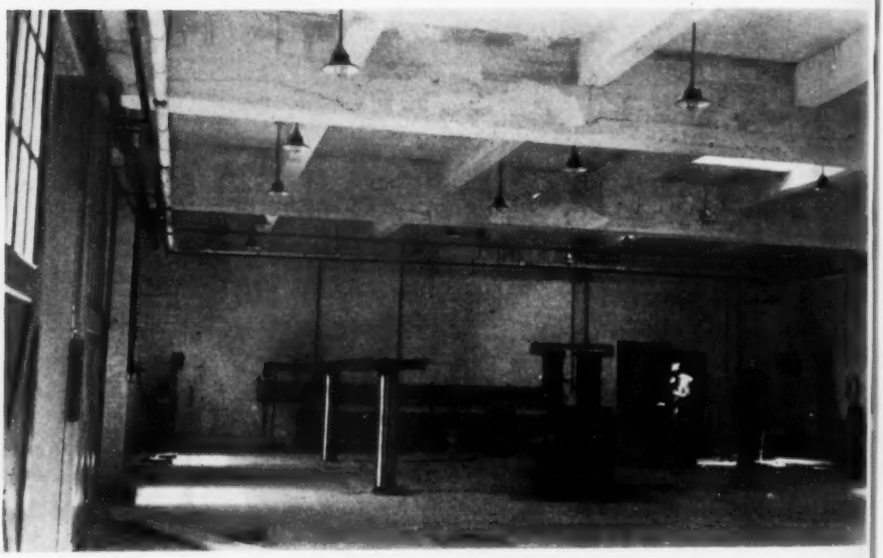

FIG. 4. Interior of Garage at West New Brighton

second story, as well as the third, was suspended from the roof trusses. In order to make these floors fit to carry larger loads it was decided to cut the second floor from its roof support and provide direct support from the ground. Considerable difficulty was encountered in the construction of the footings to carry the ground and second floors, inasmuch as the earth was found to contain a great deal of ground water.

The cost of these projects was borne by the W.P.A.

Numerous Buildings under Construction

The following buildings are now under construction:

1. An extension is being made to the existing garage and repair company headquarters in our West New Brighton Yard, facing Castleton Avenue, borough of Richmond. This extension is 2½ stories in height. Figure 3 is a rear view of the extension as seen from the yard. Figure 4 shows the hydraulic lift and interior of the garage contained in the bulding. Besides the garage there is a store room and a boiler room.

2. Alterations being made to our West 96th Street coal house, borough of Manhattan, consist of fireproofing the entire building.

3. Alteration of Grant City pumping station, involving the conversion of an old boiler room about 65 feet by 54 feet in area, and 28 feet high, into a two story building, by the erection of a mezzanine floor.

4. Superstructure building, gatehouse No. 5, Jerome Park Reservoir, borough of the Bronx, one story, 91 by 131 feet in area.

5. New superstructure over gatehouse No. 7, Jerome Park Reservoir, borough of the Bronx.

6. Alteration of Highbridge Pumping Station, located at the Highbridge Park, opposite West 175th Street, borough of Manhattan.

7. The northerly portion of the Jerome Pumping Station, about 200 feet in length and 50 feet in width is now undergoing extensive alterations, which include the construction of a new mezzanine floor for a distance of about 110 feet, to provide needed space for storage of department records. Behind the Jerome Pumping Station, six buildings have been constructed. These include a machine shop, office, garage, storehouse, etc., and are shown in fig. 5.

8. Work has been begun on a storage building at our East New York pipe yard, Brooklyn. This building will be 88 by 80 feet and two stories high.

The Department of Water Supply, Gas and Electricity was among the first to avail itself of the offer of the Federal Government to finance worthy "white-collar" projects. While it was difficult to secure competent personnel to carry on the work of several of the projects sponsored by the department, the data collected and computed by employees of the Works Progress Administration are invaluable to the City, and could not have been obtained through ordinary channels. Following is a brief description of the projects that were sponsored by the department:

FIG. 5. Various Buildings Erected at the Jerome Pumping Station

1. A house to house inspection for "leak and waste" was made. An examination was made of faucets and other outlets, and also of plumbing fixtures. Owners were notified to repair leaky fixtures. After repair this type of leak will gradually reappear, and therefore the inspection must be periodic.

2. A study was made of underground waste. The department has 4,800 miles of mains, 129,000 valves, 73,000 fire hydrants in the service. There are 635,000 taps, and approximately 3,600 miles of service pipes. Many leaks occur on these structures from which the water does not come to the surface.

3. Surveying and plotting service pipes was another project. For the past twenty years the department has a good record of all services

installed during that time. For services installed previous to that time the information is not complete or reliable, and the W.P.A. is making a survey to complete the records.

4. Subsurface structures are being mapped. The surveys for the borough of Manhattan are completed. The mapping is nearly completed. Survey work is under way in the borough of Brooklyn.

5. Another survey is that of water consumption for different classes of buildings.

Investigation of Main Sterilization

By C. K. Calvert

FOR about ten years, it has been Indianapolis Water Company practice to see that the pipe going into new lines is free from visible dirt and to place a small amount of calcium hypochlorite in each length as laid. When completed, the line was filled slowly, allowed to stand for a half hour and flushed thoroughly.

When the record of the Kingsbury and Adams (J. N. E. W. W. A., March, 1937) study on the bacteria in hemp appeared, our former practice was examined critically. It was found that filling a line slowly meant, to the construction crew, opening the valve somewhat less than full. Actually, all of the hypochlorite was flushed to the far end of the line and much of the new pipe not subjected to the action of the chlorine at all.

A careful use of the hypochlorite method of main treatment resulted in obtaining good samples from a new line just after flushing but on subsequent days the counts rose and coliforms were present in small portions of the water.

In published accounts of the treatment of new mains, various plans are followed involving the use of hypochlorite in the mains and in hemp or the addition of chlorine as gas or hypochlorite after the line is finished. All authors and several operators, verbally or in correspondence state that good samples are obtained as soon as the chlorine bearing water is flushed out. Our own experience substantiates this statement. But if the new main is sampled again in a few days the water is not good. It is easy to treat a main so that it will deliver good water *at once* but it is a hard matter to treat it so that the water will *remain* good as the days go by especially in summer.

Incidental to the preparation of "Standard Specifications for Lay-

This is a part of a paper presented at the Indiana Section meeting at Indianapolis, April 26, 1939, by C. K. Calvert, Chemical Engineer, Indianapolis Water Company.

ing Cast-Iron Pipe" under the chairmanship of W. C. Mabee, the Chief Engineer of this Company, a review of current American practices was made. The directions outlined in the published specifications represent the best practice which could be outlined at the time the report was made. But the opinion developed among some of us that some general factor was affecting the situation and leading to much confusion in acceptance testing of newly laid mains.

The Kingsbury and Adams report caused us to concentrate on the caulking material. Their results were checked and substantiated in general. Jute was found to be worse than hemp and even good quality cotton yarn was found capable of feeding the natural bacteria in water, causing enormous aftergrowth in tap water.

Limitations of Methods of Sterilizing

Hemp may be sterilized by wet or dry heat but such treatment does not prevent subsequent growth of bacteria. Treatment of hemp with effective concentrations of chlorine destroys the fibre and bacterial growth occurs when the chlorine is gone.

An organic mercurial sold under the trade name of Klerol (Reilly Tar & Chemical Co.) seems to leave enough of the active substance fixed in the hemp to prevent aftergrowth for a considerable period.

Two methods of testing hemp have beeen used:

Flow Through Method. A weighed length of hemp is coiled in a quart bottle which is supplied with tap water at a rate which will give a complete change of water in the bottle in two hours.

3-Day Cycle Method. A weighed portion of hemp is placed in a sterile quart glass stoppered bottle and 900 ml. of tap water added. The braided hemp is torn apart to expose single fibres. The bottle is stored at 20° C. for 3 days, portions removed for bacteriological examination, the water drained off and fresh tap water added. This is repeated for any desired length of time.

The 3-day cycle method gives more extreme results and is probably most satisfactory.

In the current series being examined in this manner, none have developed coliform organisms. The bacterial counts have increased in the treated hemp samples in this order, mercuric chloride alone; physiological salt solution; copper sulfate and sodium carbonate; cupric ammonium and Klerol about equal. These results indicate that Klerol and cupric ammonium will hold bacterial counts down in hemp for more than 60 days at 20 C.

A 6-inch cast-iron pipe 6 ft. long was swabbed with Klerol and plugged, using Klerol treated hemp. Tap water was passed through it at a rate to provide about 3 days retention. The temperature was 14° C. The counts remained low for 30 days.

The pipe was then removed to a location in which the temperature was 22°C. At the same time, two more pipes were added to the test. One pipe was swabbed with Klerol and the other was put in test just as it came from the storage yard. It contained visible dirt. Both pipes were plugged using heat sterilized lead wool in the joints instead of hemp. The three pipes have been in test for 60 days. The old pipe, which was removed from a cold to a warm location produced high counts at once which are still increasing. They are now higher than those from the dirty pipe jointed without hemp.

It appears that the normal tap water bacteria multiply at the temperature provided, though they do not do so in bottles at 20 C. The Klerol treated hemp seems to have lost the effect of the sterilizing agent and to be in a condition to supply food for bacteria.

800 Samples Tested

During the summer of 1938 nearly 800 samples of water from 37 new mains, all but one treated in some manner, were examined for total counts and the presence of coliform organisms in 5 ten ml. amounts. In addition, considerable chemical work was done in the laboratory and field. It was found that fire hydrants generally yield bad samples. In all of this work a special sterile tap was used and protected against air contamination.

In the summer, few of the lines laid were perfect though many of them were nearly so. The Klerol treatment of hemp and pipe does not guarantee that the lines will deliver as good water as it receives. However, any degree of concentration of Klerol in a solution used to treat hemp will improve the condition of the water delivered by the lines and the character of the water will improve with increased concentrations of Klerol up to some point beyond 1:25 which is not definitely established.

The chlorination of new mains, laid with untreated hemp, is futile. Chlorine appears not to penetrate the hemp and even if it does, the bacteria will grow when the chlorine is gone.

The following is an example. A 12-inch line, 640 ft. long was laid with no treatment of the pipe or hemp but care was used to keep out dirt. After laying, it was flushed thoroughly. Chlorine was applied.

At the end of 43 hours it was removed and at this time more than 90 p.p.m. of residual was found.

Twenty minutes after the last trace of chlorine was found, 15 ten ml. portions were planted, none of which contained gas formers. The counts were 5 or under per ml. Twenty-one hours later, the counts averaged nearly 500 per ml. and of 20 one ml. portions, 18 contained coliform organisms.

LEFT. Joint packed with jute and poured with a plastic sulfur compound. Rubber packing of tubular type in various sizes is also shown.

RIGHT. Joint packed with tubular rubber and poured with plastic sulfur. Double thickness of rubber shown at point where lap in the material would be made in actual practice. Also shown are two specimens of wedge shaped rubber packing and one of braided fibre.

The line was sampled frequently for a period of 56 days. It showed some improvement toward the end but even then about 5 per cent of the one ml. portions contained coliforms and the counts were higher than normal.

After two years of work, which has been quite extensive, it is felt that the condition of new mains has been very greatly improved, but that present methods are not perfect.

A new yarn substitute has been developed by Hayes R. Kuhns.

It is heavy walled rubber tubing. Experimental lines have been laid with it in about a dozen cities. It is receiving a warm reception because it is easier to handle, faster to put in place and will keep the joint dry on a repair job. Its cost per joint is substantially the same as for hemp. It has been under laboratory observation experimentally for 90 days and has shown no indication of increasing the bacterial count or contributing coliforms to the water either in the "3-day cycle" or "flow through" tests. The effect of rubber on taste has not been determined but it is believed to be unimportant.* The packing material will be sold under the name "Flex-Sani-Pac."

In order to get good water at once from a new line laid with rubber it would appear that the line should be swabbed with Klerol, or equal, when laid, or that it should be chlorinated heavily after laying. A line so laid and treated should be bacteriologically satisfactory.

Mains have been laid for at least a century with only recent attention to sterilization before use. Apparently the bacteria in hemp do not cause human illness but such bacteria do not come labeled and they cannot be distinguished from significant coliforms. If packing bacteria are disregarded, significant ones may be missed.

It seems unjustified to lay a new main under any but the best conditions possible to impose. Fortunately for those persons in the field who have been studying the problem of bacterial growths in newly laid mains, the possibility of substituting a practically inert material such as rubber for bacterial-growth-promoting materials such as hemp or jute is a welcome event. If by the use of the new material, the problem can be solved, a great service will have been rendered water works men.

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* EDITOR'S NOTE: Rubber has been used in sleeve-type joints for many years. There appears to be no record of taste production under those circumstances.

Comments On Report On Depreciation

By Reeves Newsom

THE Report of the Special Committee on Depreciation, rendered to the National Association of Railroad and Utility Commissions in November, 1938, is an able presentation of the arguments in favor of the age-life basis for determining depreciation in general and the use of the straight line method of computing it in particular.

From the viewpoint of simplification of accounting, the arguments for straight line depreciation are undoubtedly convincing. In the case of short lived property such as constitutes much of the plant used by the telephone and electric utilities and where a substantial amount of information is at hand regarding the service life of a majority of the facilities, the difference may be very small between straight line depreciation accounting and the use of the average of actual retirements and replacements as a basis for the annual provision. Also because of the young average age of most of the equipment in these industries and the relatively frequent changes in rates for service that have taken place, the amount of injustice that may be done by computing the depreciation accrual as of the present time on a straight line basis may not be too severe.

When we view the effects of suddenly applying the age-life theory of depreciation, especially when straight line computations are used, to long lived property such as makes up water systems, many of which have been operating for a half century or more, the picture is very different.

Even in the case of water plants, the difference between age-life depreciation applied on a straight line basis and any other form for use in the future would not necessarily be vital, if the facts regarding

A discussion contributed by Reeves Newsom, President of the A. W. W. A. and Engineer-Consultant, 500 Fifth Avenue, New York City. The Report to the National Association of Railroad and Utilities Commissioners has been published by the State Law Reporting Co., New York, under the title "Depreciation Principles and Methods."

retirements of water works facilities were known. But such is not the case. With the exception of a relatively small part of the total investment represented by short lived property and pipe less than 4 inches in diameter, there does not seem to be available for common use a complete history of retirements of property installed in a sizeable water system.

The result has been that estimates of service life of water property including cast-iron pipe and impounding dams have usually been based upon the retirements that are known about, without regard to the proportion of the property surviving and to remain in use for years to come. Furthermore, it has not been the custom to make any allowance for the fact that if the assumed life expectancy of facilities is a certain term of years when they are installed, the total life of the part of such facilities still in service today will be substantially greater than the original assumption. The effect of neglecting this consideration is proportionally greater in plants that have property that has been in use for a long period of years.

Effect of Straight Line Methods in Older Plants

The contention in this committee report is that it does not matter whether or not an error is made in the assumption of the service life, inasmuch as the owner of the property will receive either a return *on* his property or the return *of* his property from the rate payer. It seems fairly obvious that, even if this were granted for sake of argument *as to the future*, in the case of a water plant which has been in existence 40 or 50 years, to begin abruptly to figure the accrued depreciation on a straight line basis, using service lives that are relatively short, will certainly deprive the owner of his property inasmuch as the rates have never reflected a yearly provision for depreciation based upon such assumptions, and the rate payers have not provided for the amount of depreciation so computed.

It, therefore, makes a great difference as to whether or not the assumed lives are too short, if a computed accrued depreciation as of the present time is going to be used in establishing the value of the plant upon which a return is to be allowed. Furthermore, while the committee's report deals almost entirely with the effect of depreciation upon rates, the finding of excess accrued depreciation by the use of the straight line method and too short lives for the property, even though originally for rate purposes, will likewise result, even more quickly, in confiscation of property if the sale or

condemnation of the plant is subsequently forced by the action of the municipality served.

The owners of water plants as a class have not therefore dared to subscribe to age-life depreciation because of the possible abuses resulting from the use of too short service lives and the computation of a ruinous amount of accrued depreciation by the straight line method which amount had not been collected in the past, could not be collected in the future, and which bore no relation to actual existing depreciation in the plant. In actual practice contentions have been made in rate hearings that property so located and so well preserved physically that it would continue in service for many years in the future should be considered fully depreciated and deducted from the rate base merely because it had attained a certain arbitrarily selected age without the slightest consideration of whether or not such depreciation had been provided for in the rates. There is the further possibility that the adjusting of the books to reflect such depreciation accrual would throw a company's surplus so far in the red that impairment of credit needed to extend service would result and there would be the danger of bankruptcy because of inability to pay interest charges on funded indebtedness even though earned.

Difficulties from Incorrectly Estimated Service Lives

If water works plants generally had shown high earnings in the past this situation might not be so serious. But the contrary is true. Long lean periods following the original construction and the addition of major units of supply is the ordinary history of water works plants. Higher rates to provide larger amounts for depreciation would have served merely to prolong such lean periods and resulted in even smaller reserves for depreciation.

Even as to the future, the statement that it makes no difference whether or not service lives that are too short are used is not correct as to long lived facilities such as constitute a major portion of a water plant. If the rates provide too rapidly for the depreciation of property and if the amount so accrued is used as a deduction in determining the rate base, the consumers in the present generation will be paying too much, so that in the next one, service may be furnished at rates less than the then consumers are entitled to; and the owner will have been forced to take back and reinvest funds which were satisfactorily placed and well protected by tangible serviceable property values, and to continue to be responsible for the operation

and management of useful property upon which no return can be earned.

Until more information is available as to the actual service lives of cast-iron pipe six inches and larger in diameter and of impounding dams and reservoirs, the use of the straight line application of age-life depreciation is not a panacea for the valuation problems of water plants. When knowledge supplants guess work as to the number of years these facilities, which form such a large part of a water works system, will adequately function, the argument in favor of substituting a mathematical computation in the determination of accrued depreciation for expert opinion based on observation and experience will have gained some strength.

A Proposed New Method for Determining Barrel Thicknesses of Cast Iron Pipe

By Thomas H. Wiggin, M. L. Enger, and W. J. Schlick

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1. Introductory

This paper is the first attempt to explain in a document for circulation outside of the American Standards Association Sectional Committee A-21 on Specifications for Cast Iron Pipe and Fittings the development of the method of designing barrel thicknesses of cast

A paper presented orally at the New Orleans Convention, April 28, 1938, by Thomas H. Wiggin, Consulting Engineer and Chairman of Sectional Committee A-21 on Specifications for Cast Iron Pipe and Fittings; M. L. Enger, Dean of the College of Engineering and Director of the Experiment Station, University of Illinois; and W. J. Schlick, Research Professor, Iowa State College. Submitted for publication April 28, 1939.

iron pipe which has resulted from about 10 years of research and study by that committee.[1] Committee A-21 was organized under the rules of the American Engineering Standards Committee, now American Standards Association, and is sponsored by the American Gas Association, The American Society for Testing Materials, the American Water Works Association and the New England Water Works Association.

The authors of this paper have all participated from the beginning with others in the work of this committee. The parts of the paper relating to the history of previous methods and to general descriptions and application of the new method were written by Mr. Wiggin; those relating to tests at the University of Illinois by Dean Enger; and those relating to tests at Iowa State College, theory of combined exterior loads and internal pressure, and determination of earth and truck loads were written by Professor Schlick. The whole paper has been scrutinized by each of the co-authors.

2. Historical

The fundamental formula for design of a thin cylinder under internal fluid pressure is very old and has been in whole or in part the foundation of all the formulae which have been used in the design of pipe since engineering became a technical art. This formula is as follows:

$$t = \frac{pr}{S} \quad \text{or} \quad t = \frac{pd}{2S},$$

in which t = thickness of pipe
p = internal pressure
r = internal radius of pipe
d = internal diameter of pipe
S = allowable working stress in metal.

In English speaking countries the units are inches and pounds per square inch.

As applied to cast iron pipe this fundamental formula has been modified in various ways by various practical water supply engineers

[1] Publication having been delayed about a year since the paper was delivered at the A. W. W. A. Convention in April, 1938, another paper by W. D. Moore, also of Sectional Committee A-21 the American Standards Association, has since been delivered (in April, 1939) before the Distribution Section of the American Gas Association.

to include allowances for water hammer and for handling, foundry inaccuracies and corrosion. In effect water hammer is actually added water pressure and the proper internal pressure for use in the fundamental formula must include it and not merely the static pressure. Because of the uncertain magnitude of the portion of pressure caused by water hammer, it has always been shown separately in these formulae.

Modification of the fundamental formula to provide a combined allowance for handling, foundry inaccuracies and corrosion has never had and can not have a rational mathematical basis. The foundry inaccuracies to be provided for are definite, being a matter of specification and inspection, but the two other factors are indeterminate and the combined allowance has merely expressed mathematically the judgment of some engineer or group of engineers. It will become evident as the paper progresses that the element of judgment still continues to play the largest part in the selection of thicknesses for the smaller pipe, which constitute by far the greater part of the tonnage of cast iron pipe.

What are probably the best known to water supply men of these modifications of the fundamental thickness formula will be given below.

The Dexter Brackett or New England Water Works Association Formula. Mr. Brackett was for many years engineer of the Boston Water Works, and then successively department and chief engineer of the Metropolitan Water Board, now the Water Division of the Metropolitan District Commission in Massachusetts. His formula was in use earlier than 1895 and was used by the Metropolitan Water Board from 1895 until rather recently and in the cast iron pipe specifications of the New England Water Works Association, of which specification committee he was chairman. It is as follows:

$$t = \frac{(p + p')r}{3300} + 0.25,$$

in which t = thickness in inches,
p = static pressure in pounds per square inch,
p' = pressure, in pounds, allowed for water ram,
r = internal radius of pipe in inches,
3300 = $\frac{1}{5}$ tensile strength of cast iron, taken as 16,500 p.s.i.
0.25 = allowance for deterioration by corrosion and other causes.

The description of this 0.25 allowance is as stated in a document prepared under Mr. Brackett's direction. However, foundry tolerances were actually included in this allowance as the specified tolerances were the same as the present tolerances of the A. W. W. A. specifications, and were the origin of the A. W. W. A. allowances.

Mr. Brackett paid attention to water hammer or water ram, as it was generally called then, and tried to judge its magnitude by indications of recording gages and otherwise. He chose for his water ram allowances the figures to be used for p′ in his formula as shown in table 1. A committee of the A. W. W. A. recommended these same allowances for water hammer but the authors cannot find that they were used in computing the A. W. W. A. thickness schedules; instead a flat figure of 100 lbs. appears to have been used.

TABLE 1

Dexter Brackett Allowances for Water Ram

PIPE DIAM.	WATER RAM, p′
inches	*lbs.*
3 to 10	120
12 & 14	110
16 & 18	100
20	90
24	85
30	80
36	75
42 to 60 incl.	70

The importance of the arbitrary thickness addition of 0.25 inch will be obvious by noting that for a 6-inch pipe designed for 200-ft. head the thickness without this addition would be only .19 inch. The corresponding thickness for a 12-inch pipe at 200 ft. head would be .36 inch.

The Jas. T. Fanning Formula was apparently used in modified form in computing thicknesses for the schedules of the American Water Works Association specifications.

The Fanning formula is as follows:

$$t = \frac{(p + 100)d}{0.4S} + 0.333\left(1 - \frac{d}{100}\right)$$

where t, p, and d are thickness, static pressure and diameter as before, and S the ultimate tensile strength of the cast iron in lbs. per sq. in.

The first term in the value of t is the fundamental formula with a factor of safety of 5 just as in the Brackett formula. The second term is an arbitrary allowance which varies from 0.32 in. for a 3-inch pipe to 0 for a 100-inch pipe. For a 25-inch pipe the computed thickness is the same as for the Brackett formula.

The American Water Works Association Formula came to one of the authors in the form:

$$t = K(H + 230) \times d + 0.333 - .0033d$$

$$\text{where } K = \frac{.5 \times 0.433 \times \text{Factor of Safety F}}{\text{Ultimate Strength S}}$$

H is the static head in feet.

Those with a little mathematical facility will recognize that this A. W. W. A. formula, assuming a factor of safety of 5 as in the Fanning formula as above given, is the same as the Fanning formula, since the 230 feet is 100 lbs., the figure 0.433 in the value of K turns feet head into pounds, and the product of $.5 \times F = .5 \times 5 = 2.5$ or $\frac{1}{.4}$; further, the quantity $0.333 - .0033d$ is the same as $0.333\left(1 - \frac{d}{100}\right)$.

TABLE 2

Comparison of Pipe Thicknesses Computed by A. W. W. A. Formula with Those in A. W. W. A. Specifications

DIAM.	CLASS	COMPUTED BY FORMULA	A. W. W. A. TABLES
12 inch	B	.62	.60
48 "	C	1.71	1.71
24 "	A	.76	.73
20 "	H	1.51	1.51

Our informant stated that in the A. W. W. A. tables the factor of safety F was 5 and S was 18,000 lbs. The formula then works out:

$$t = .0000604(H + 230)d + 0.333 - .0033d$$

The authors have applied the above formula at random in trying to check the A. W. W. A. thickness tables. A few comparisons are as given in table 2.

It will be noted later in this paper that although the tensile bursting strength of metal in pit cast pipe is assumed to be 16,500 p.s.i. in the Brackett formula and 18,000 p.s.i. in the A. W. W. A. formula (and these are very conservative figures in comparison with the tensile strength of small specimens) the bursting tests of pit cast pipes themselves, considering the lower values occasionally found in the tests, will not support a conservative design strength of over about 11,000 p.s.i., which is the figure used in the work of Committee A-21.

The Fairchild Formula. This was developed by Mr. I. J. Fairchild in connection with the Federal specification for deLavaud and other special types of pipe. This formula was first published in 1927 (1) and was modified a few years later. The two editions are as follows:

$$\textit{Original, } t = \frac{fd(p + p')}{2S} + \frac{0.30}{d^{0.3}}$$

$$\text{Modified, } t = \frac{fd(p + p')}{2S} + \frac{0.28}{d^{.15}}$$

f is a factor of safety which, for centrifugal pipe, was taken as 4 in the original formula and as 5 in the modified formula.

S is the ultimate bursting strength of the metal in pipe, taken as 20,000 p.s.i. in the original formula and 25,000 p.s.i. in the modified formula.

p′ is water hammer, taken 5 or 10 lbs. larger than the Dexter Brackett allowances in sizes 16-inch and 24-inch inclusive, but the same as Brackett for smaller sizes.

The first term in the value of t will be recognized as the fundamental formula for cylinders. The second term is an arbitrary allowance for handling, foundry inaccuracies and corrosion. In the modified formula it works out as 0.23 inch for 4-inch pipe and 0.17 inch for 24-inch pipe.

The Allen Hazen Formula. Mr. Hazen, eminent sanitary engineer, with his usual clarity of thought and genius for putting relatively abstruse matters into terms for general use, devised or adapted a formula for computing thickness of pipe in which both the tensile fibre stresses caused by deformation or flattening of the pipe under trench load and the direct tension caused by internal water pressure are taken into consideration, the one being added to the other and the total kept within the assumed working stress obtained by dividing the ultimate strength by a factor of safety. This matter is too

complicated for inclusion in this historical introduction but reference is given (see reference 2 at end of paper).

One of the authors, T. H. Wiggin, used similar methods previously in designing 48-inch cast iron pipe under extra heavy fill. The Flinn, Weston, Bogert *Water Works Handbook*, 1916 ed. page 385, and 1927 ed. page 383, contains a development of similar methods.

3. Genesis of Proposed Method of Determining Barrel Thicknesses of Cast Iron Pipe

The group of water supply and gas engineers who took up the organization of Sectional Committee A-21 on Specifications for Cast Iron Pipe and Fittings, after the appointment of the members, obtained the generous financial and mental cooperation of the cast iron pipe manufacturer members in a program of tests originally outlined by T. H. Wiggin. The program included as of primary importance the experimental investigation of the effects of combined trench loads and internal pressure on cast iron pipe.

Not long after organization the Committee developed this program by ideas contributed by its members and arranged with the University of Illinois and Iowa State College to carry out the tests. Tests relating to bursting, impact and other miscellaneous qualities of cast iron pipe were assigned to the University of Illinois and came under the direction of Dean M. L. Enger, one of the authors of this paper, who succeeded Dr. A. N. Talbot as head of the Department of Theoretical and Applied Mechanics at the University of Illinois. Dr. Talbot will be remembered by this association for his illuminating and original contributions to the A. W. W. A. Journal (5) on strength of 6-inch pipe.

Tests relating to the effect of trench loading both alone and combined with internal water pressure were assigned to Iowa State College, where Dean (now Dean Emeritus) Anson Marston and his assistants had for long been developing, by experiments and theoretical reasoning, the laws of trench loads and truck loads. Another of the authors, Professor W. J. Schlick, long an assistant to Dean Marston, was put in charge of this work for Iowa State College.

The Sub-Committee of Sectional Committee A-21 which was charged with oversight of these experiments agreed with Professor Schlick that the laboratory tests should be devised to simulate, as well as was practicable in laboratory apparatus permitting the measurement of applied weights and reactions, six different conditions

of pipe laying, four of them ordinary and two unusual, which in the course of time became lettered A to F inclusive, and are as follows:

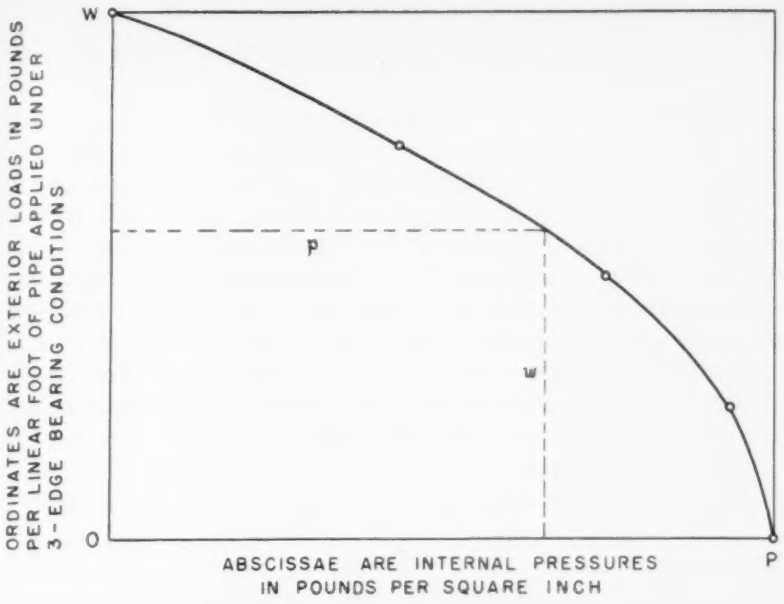
Field Condition A—Flatbottom trench, backfill untamped.
Field Condition B—Flatbottom trench, backfill tamped.
Field Condition C—Pipe on blocks, backfill untamped.
Field Condition D—Pipe on blocks, backfill tamped.
Field Condition E—Pipe on hollowed earth trench, backfill untamped.
Field Condition F—Pipe on hollowed earth trench, backfill tamped.

Field conditions E and F have been used for sewers but not for water pipe unless somewhere[2] recently owing to the knowledge that the greatest factor of safety would result thereby. Figure 22, included with explanations further on in this paper, illustrates the actual field conditions and the laboratory simulations which were used in field conditions A, B, E and F. Field conditions C and D were similar to A and B respectively, except that two cross blocks per 12-ft. length of pipe were substituted for the flat bottomed trench.

4. Explanation of Proposed Method of Determining Barrel Thicknesses

General Statement. A pipe may be broken by internal pressure alone or by trench load alone or by an infinite number of combinations of intensities of internal pressure and trench load. Where the internal pressure is high the trench load necessary to finish the breaking is low and *vice versa*. By experiments at Iowa State College the relationship of the intensities of trench load and internal pressures at breaking was determined. This relationship, which is well enough represented by the parabola shown on fig. 1, first proposed by Professor Schlick, was not in general determined for the field conditions of laying, viz. A, B, C, D, E and F, outlined above, but with the laboratory condition of exterior loading known as *3-edge bearing* (see fig. 2) which is somewhat more taxing on the strength of the pipe than is field condition A, viz. that with flatbottom trench and no tamping. The 3-edge bearing test is the standard and generally used method for testing drain tile, sewer pipe and cast iron culverts (3), and, since the Talbot tests on 6-inch water pipe (5), has been extensively used in foundry control of the quality of cast iron water pipe.

[2] Recent specifications of the Metropolitan Water District of Southern California prescribe condition F (with further a void $\frac{3}{8}$ inch deep under the center of the pipe) for lines of reinforced concrete and steel pipe about 50 inches in diameter.


W
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P
ORDINATES ARE EXTERIOR LOADS IN POUNDS PER LINEAR FOOT OF PIPE APPLIED UNDER 3-EDGE BEARING CONDITIONS
ABSCISSAE ARE INTERNAL PRESSURES IN POUNDS PER SQUARE INCH

FIG. 1. Load-Pressure Curve

Explanation: Load-pressure curve is a parabola with apex at **P**. Equation is $w = \frac{W}{\sqrt{P}}\sqrt{P - p}$. **P** is the bursting pressure of the pipe when no earth or other exterior load exists. **W** is the crushing load per lin. foot of pipe when no internal pressure exists. **p** and **w** are any combination of internal pressure and external load which together will just cause fracture.

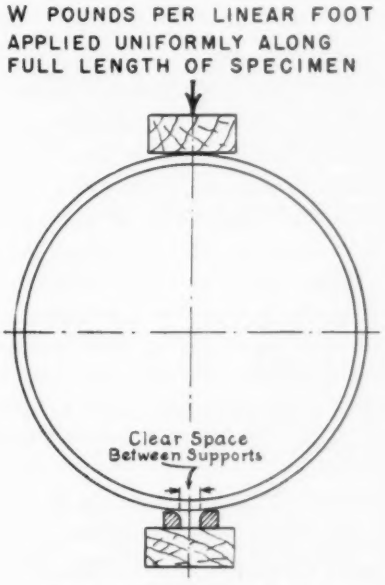


FIG. 2. Three-Edge Bearing

By other tests, and by the background of tests made over many years at Iowa State College, relations or so-called ratios *to three-edge bearing* were found for each of the field conditions of laying A to F as explained in Section 11 of the paper. These ratios represent the resistance of pipe to fracture under trench load, when laid in the various methods A to F, relative to its resistance when tested with 3-edge bearing. By applying the appropriate ratio as a divisor to the estimated load resulting with any of the conditions of laying, A to F, such load is transposed into a load to be used in the formula for fundamental relationship between water pressure and trench load at breaking with a pipe supported in 3-edge bearing.

The process of design then reduces to the following steps:

1. Obtain internal pressure by adding together static and assumed water hammer pressures.
2. Estimate trench load per foot of pipe by use of formulae developed from experiments at Iowa State College or by use of diagrams based on these formulae. Add an allowance for truck load. The Committee assumed two passing trucks with adjacent wheels 3 ft. apart center-to-center, 9,000 lbs. on each rear wheel plus 50 per cent impact.
3. Divide the total trench load by the 3-edge bearing ratio corresponding with the method of laying, A to F, to be used. For support on blocks, except for tamped trenches with pipes 20-inch and larger, this ratio is less than unity and will in effect make the corresponding 3-edge load greater. For pipe laid on the trench bottom with backfill either tamped or untamped, the ratio is greater than unity and the 3-edge load equivalent in destructive effects will be less than the actual estimated load.
4. Multiply both water pressure as in paragraph 1 above and equivalent 3-edge trench load as in paragraph 3 above by the assumed factor of safety, which Committee A-21 has taken as 2.5. With the water pressure and the trench load, thus increased, as coördinates, obtain by the formula of relationship previously described or, more easily, from a diagram, the thickness of a pipe which would just fail. This will have a factor of safety of 2.5. The computed thickness is to be increased by adding two allowances, viz. the foundry tolerance and a corrosion allowance.

For small pipe and ordinary depths of cover the thicknesses as above computed are generally smaller than thicknesses determined by judgment to be required for handling. Where they

are smaller, it is proposed to replace them by these minimum thicknesses determined by judgment.

In case of pipe laid on blocks with backfill not tamped, viz. Field Condition C, thicknesses of pipe 6 inch and less in diameter, under deep covers, are in some cases determined by their strength as beams spanning between blocks. In this case the spacing of the block is very influential; the common position of blocks, viz. close behind the bell and about $2\frac{1}{2}$ ft. in front of the bell, produces alternately a long and a short span between block supports, and the long span requires extra thickness of pipe to make the beam strength sufficient. An evening-up of the block spacing greatly reduces the bending moment. Pipe longer than 12 ft. require a corresponding increase in frequency of blocks.

A more detailed explanation of the relationships and the empirical constants used in design will be given in succeeding sections of the paper, followed in the last section by some practical illustrations of the actual processes of computing barrel thicknesses.

5. Fundamental Relationships of Internal Pressure and External Load

Each pipe under an earth fill is subjected to external vertical loads, and under certain conditions to horizontal loads as well. Each of these systems of load tends to deform the pipe to an elliptical shape with the short diameter parallel to the direction of the line of action of the load, thus producing bending moments and flexural stresses which are similar in character to those in a loaded beam. The moment, and the stress, in a given ring depend upon both the magnitudes and distributions of the loads. But, so long as those are known, the net moment can be calculated, and indicates the flexural stress at that section.

The maximum moment for a given pipe or ring is that indicating a flexural stress equal to the flexural strength of the metal. This is a property of the ring; failure will occur whenever the moment, and the stress, reach this value irrespective of the magnitude and distribution of the loads which produce them. Since the flexural stress as calculated with the ordinary formula varies directly with the moment (in a given case), calculation of the loads necessary to produce the maximum moment, or a given lower moment, furnishes a ready means for comparing the supporting strengths of this ring under different conditions of external load and support.

The application of internal fluid pressure to such a ring produces

outward, radial forces which are uniform around the inner circumference. These forces produce uniform circumferential tension in the whole wall, and tend to split the pipe. But since these forces are uniform, they can produce no bending moment or flexural stress. When the ring is deformed by external forces the total vertical and horizontal components of the outward radial forces are unbalanced slightly, but the moment so produced is so small that it may be neglected.

A cast iron pipe installed underground in a line carrying water or gas under pressure is subjected to a circumferential flexure which varies in intensity and sign around the circumference, and to a circumferential tension which is uniform in all parts of the wall. Since cast iron is weaker in tension than in compression, the critical stress will be the combination of the circumferential tension with the flexural tension at the point of maximum moment.

It is at this point that an empirical relationship must be introduced. The designer has no reliable and convenient means of calculating the actual intensities of the flexural stress in a cast iron pipe. The ordinary flexural formula was derived for an ideal material in which stress is always proportional to strain, and the neutral axis or surface in a flexure specimen is in a known and constant position. The Mc/I formula, when applied to cast iron, gives a useful measure of strength termed the "modulus of rupture." However, this is a relative value, not an actual stress; it is very near the actual stress at low loads, but as the load increases the discrepancy increases till at failure the modulus of rupture is nearly double the ultimate tension and about half the ultimate compression.

The direct or circumferential tension on the other hand can be calculated by the usual formula within close limits. But, since the calculated flexural tension is only relative, the two cannot be combined by simple addition. The character of the relationship between the Mc/I stress and the actual stress is such that an empirical relationship offers the only means of combination. In following sections are given a brief description of the tests and a mathematical analysis which resulted in the selection of the parabola previously mentioned and shown in fig. 1 as a sufficiently close approximation to this empirical relationship. The expression finally adopted for this load-pressure relationship expresses the flexural stress, as calculated by the ordinary formula, as the equivalent of that portion of the ultimate tensile strength not required to resist the circumferential tension due to the internal pressure.

6. Experimental Data for Load-Pressure Relationship

The experimental data for the load-pressure relationship were obtained by testing specimens 33 to 45 inches long from the barrels of pipe, with standard three-edge bearings and internal pressures varying from zero to 60 to 90 per cent of ultimate bursting pressure. The choice of three-edge bearings was dictated by their convenience and the fact that they insured a known and reproducible loading condition for which the moment equation and relationship to other bearing conditions had been studied experimentally. It was more convenient, with the apparatus used, to apply the desired internal water pressure, and then hold this constant during the application of the external load necessary to cause failure. There was nothing in the results, or the observed actions of the specimens, to indicate that materially different results would have been obtained if this procedure had been reversed, or if load and pressure had been increased together. It should be noted, however, that the results for each specimen were the load and the pressure which, combined, produced failure.

The most troublesome apparatus problem was that of devising suitable means for holding internal pressure without providing too much restraint against the normal deformations of the specimens under external load. Numerous methods were tried but the first which proved usable is illustrated by fig. 3. This consisted of a series of special inner rubber tubes held between the specimen and an inner pipe, and all connected to one header pipe. Bulkhead plates were bolted to a ring screwed onto the end of the inner pipe, with lengths of small air-hose to prevent the end tubes from being forced out between the bulkhead plates and the ends of the specimen. This apparatus was used satisfactorily for pressures up to 260 p.s.i.; when higher pressures were tried the tubes were cut wherever they were lapped or folded.

The arrangement used in the remainder of the tests consisted of rubber-cord gaskets placed in grooves machined in the bulkhead plates, so as to bear on the ends of the specimen and of the inner pipe (see fig. 4). This arrangement, or variations of it, was used in each subsequent test. It did cause some frictional restraint against pipe deformation, but this was determined within required limits and subtracted from the total applied load. In general, specimens were tested in sets of three.

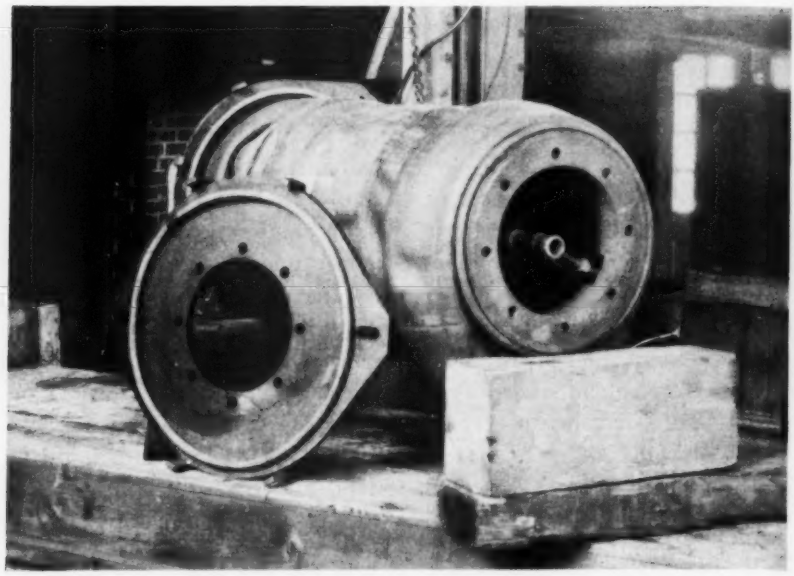


FIG. 3. The Inner Pipe, Tubes and Bulkhead Plates Used for Internal Pressures up to 260 lbs. per sq. in.

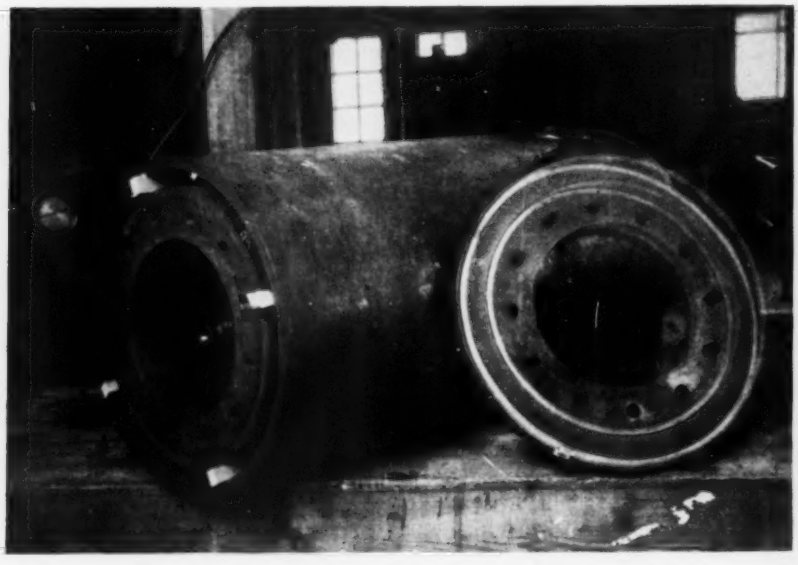


FIG. 4. A Specimen with the Inner Pipe, Bulkhead Plates and Rubber-cord Gaskets. The blocks used to center the inner pipe were not used when making a test.

7. Mathematical Derivation of Load-Pressure Relationship

The flexural stress in each specimen was calculated by first calculating the maximum moment by the elastic ring theory (ignoring the small moment due to the weight of the specimen), and then using this moment in the ordinary flexural formula. The flexural stress for specimens loaded through 3-edge bearings is

$$R = \frac{0.0795\,W(d + t)}{t^2}, \text{ which is a combination of the equations,}$$

$$M = \frac{0.159\,W(d + t)}{12}, \text{ and } R = Mc/I,$$

in which R = flexural or outer fiber stress, pounds per sq. in.;
W = external load, pounds per linear foot;
d = internal diameter, inches[3];
t = wall thickness, inches.[3]

No practicable and reliable means were found for measuring diameter changes for specimens under both load and pressure. Calculation of R with initial or unloaded dimensions introduces an error which probably does not exceed 2 per cent, being largest for specimens tested with low internal pressures.

The circumferential tension due to internal pressure was calculated with the usual formula:

$$S = \frac{Pd}{2t},$$

in which S = tensile stress, pounds per square inch
P = internal pressure, pounds per square inch
d = internal diameter, inches[4]
t = wall thickness, inches.[4]

The results of the first series of tests, with 20-inch pit cast pipe, were studied by calculating R and S for each specimen, and others averaging for each set of three specimens tested with a given (nominal) pressure. These values were plotted with values of R as ordi-

[3] The values of (d + t) were the average values (for the specimen) of diameter and thickness. The value of t^2 was the square of the average thickness along the fracture.

[4] The average internal diameter, and the average thickness along the line of the fracture.

nates and of S as abscissae, using average values from the Illinois tests for that end-point. The equation of a smooth curve through these points was of the form $S - s = \frac{r^n}{C}$, in which s and r are the stresses when both load and pressure were used, and n and C are empirical constants. The numerical value of n was near 2.0, which

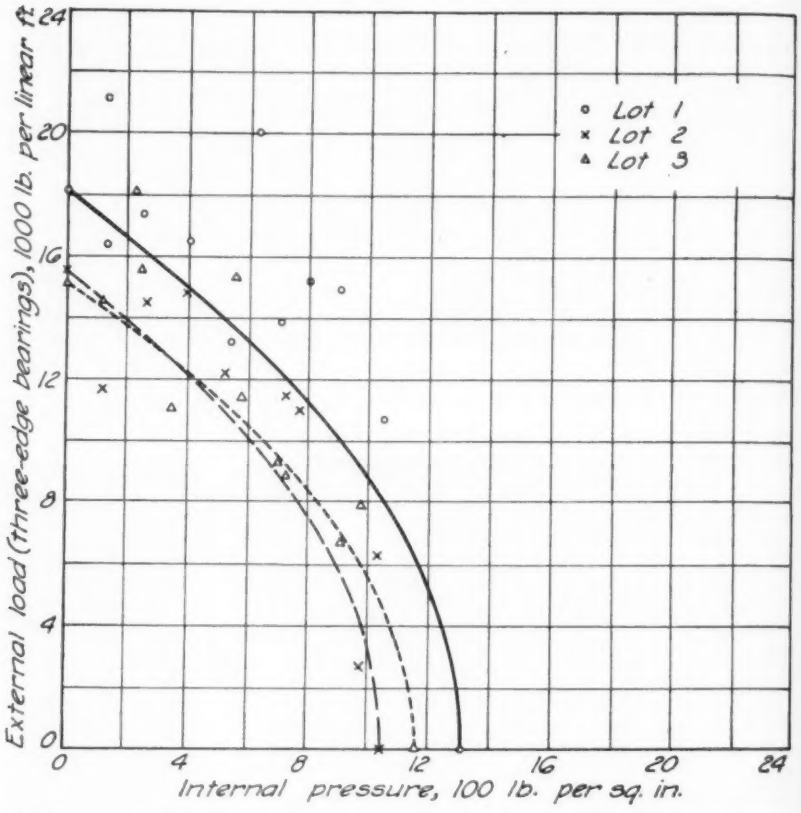


FIG. 5. Load-Pressure Curves for 20-inch Class B Pit Cast Pipe from Three Founderies.

value was adopted tentatively because of its convenience. It was noted that the value of C was approximately 3R, and that R/S was approximately 3.0, making $C = R^2/S$. This equation then could be expressed in the general form:

$$S - s = s\left(\frac{r}{R}\right)^2$$

Since these tensile and flexural stresses vary as the first power of the pressure and load, the relationship could be stated also:

$$P - p = P\left(\frac{w}{W}\right)^2$$

in which P and W are the ultimate pressure and load when the other is zero, and p and w are the pressure and load which produce failure

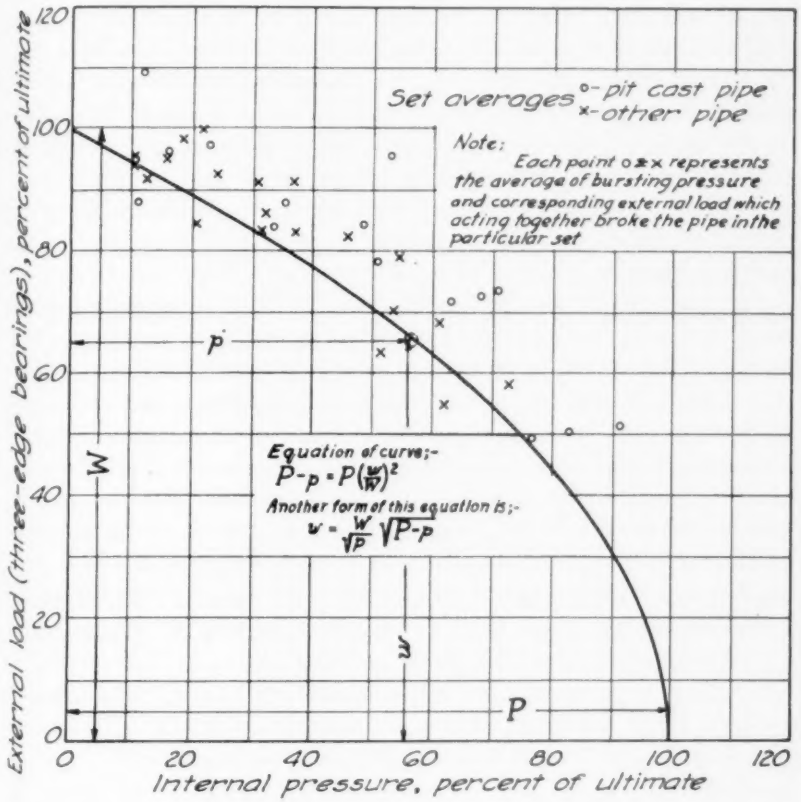


FIG. 6. Load-Pressure Relationship Found in Tests of 12-, 20-, and 48-inch Cast Iron Pipe.

when acting simultaneously. The set averages for the three lots of 20-inch pipe are shown, with this relationship for each lot, by fig. 5.

It will be noted that this relationship is general; that the position of the curve depends upon the values of the end-points; and that if these end-points are known, or are calculated from known or assumed

values of R and S, intermediate values of r or s can be calculated for assumed values of the other. The values of W and w may be in terms of any bedding or support condition so long as they are both for the same condition, though it probably will be more convenient to use this relationship in terms of three-edge load or strength and then transpose those strengths to their equivalents with particular field conditions by means of ratios to be given later.

The correlation between this relationship and the results for the 12-, 20-inch and 48-inch pit cast pipe tested for Sectional Committee A-21 and for 12-inch and 20-inch pipe of other types tested for the manufacturers are shown by fig. 6. In order to make a composite plotting for pipe from different lots, the values of W and of P for each lot are taken as 100 per cent, and the values of w and p expressed as percentages of the corresponding 100-per cent values. It will be noted that in general the plotted curve falls to the lower, or safe, side of the test values, and that it appears to be of general application to cast iron pipe.

The preceding discussions apply directly to pipe supported full-length either in the test or in the field. The load on a pipe supported on blocks is assumed to be uniform in a longitudinal direction, while the support is concentrated at the blocks, with intermediate earth support between blocks in some cases. Such block support produces a complex distribution of deformations and stresses. If the pipe fails as a ring (all pipe 12 inches and larger and some pipe as small as 6 inches do so fail) the modulus of rupture appears to be unchanged, and the principles discussed will apply. Smaller pipe (all 4-inch and some 6- and 8-inch) supported on blocks with untamped backfill will fail as beams; in these cases these principles do not apply, since the circumferential and flexural tensions act at right angles to each other. These points will be discussed more fully in Section 11 in the presentation of the data relating to the supporting strength relative to 3-edge bearing strength developed under different field or laying conditions.

8. Bursting, Ring, Talbot Strip, Beam, Impact and Other Tests Made at the University of Illinois

With the relationship of bursting and crushing effects determined, as has been explained, the problem of design becomes one of determining bursting and crushing strengths and applying them by aid of this relationship. There follows a description of some of these tests

to determine constants for design; also of tests of pipe as beams, tests made to investigate the susceptibility of cast iron pipe to impact, etc.

Internal Pressure Tests. A comprehensive series of internal pressure tests was made on 6-inch pit cast pipes, and other cast iron pipes, by Professors A. N. Talbot and F. E. Richart (4, 5). Bursting tests were made under the auspices of the Sectional Committee on Specifications for Cast Iron Pipe and Fittings at the University of Illinois by M. L. Enger and W. M. Lansford on 12-inch, 20-inch, 24-inch, 36-inch, and 48-inch pit cast pipe. The average tensile strengths found from the internal pressure tests, based on the average thicknesses of the pipes on the lines of fracture, were as shown in table 3.

In making bursting tests of pipe it is necessary to restrain the closed ends. The 6-inch pipe were tested in a restraining frame at

TABLE 3

Average Bursting Tensile Strength of Cast Iron in Pit Cast Pipe

INTERNAL DIAM. OF PIPE	NUMBER OF TESTS	AVERAGE TENSILE STRENGTHS
inches		*lbs./sq. in.*
6	36	14,200
12	11	14,570
20	10	13,950
24	2	16,550
36	4	14,132
48	8	12,380

the plant of the American Cast Iron Pipe Company in Birmingham, Alabama. The other pipe were tested in either the 600,000 lb. or the 3,000,000 lb. testing machines at the University of Illinois. The restraining frame, or the testing machine, carried most of the longitudinal load due to the internal pressure, making the tests representative of conditions in the average pipe line. The failures were always sudden. It was noted that when a pipe failed at a low pressure, due to an initial crack or other weakness, the fracture was usually on a single longitudinal line. When the pipe developed its full strength against internal pressure, a number of cracks branched away from the principal line of failure. Figures 7 and 8 show respectively a 48-inch pipe set up in the 3,000,000 lb. testing machine, and the same pipe after it was burst at a high pressure.

Since pipe must carry fluids under pressure, the internal pressure

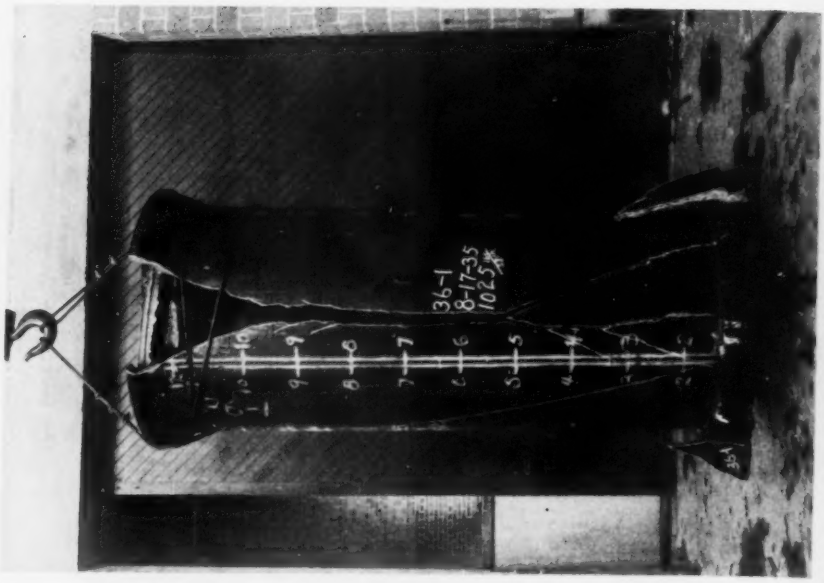


FIG. 8. 48-inch Cast Iron Pipe After Bursting Test,

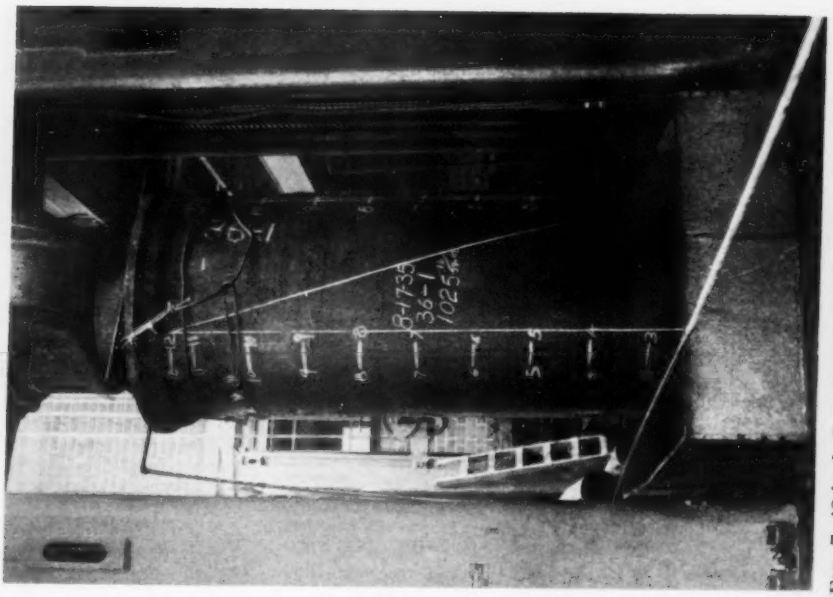


FIG. 7. 48-inch Cast Iron Pipe Ready for Bursting Test,

test is of great importance. The results of bursting tests give information on which to base allowable working stresses. While the bursting test is of primary importance, it is an expensive one because a whole length of pipe is destroyed. In order to obtain information concerning the quality of the metal in the pipe other tests have been devised. The 2-inch by 1-inch test bar, cast at the same time as the pipe, tested as a simple beam with a center load on a 24-inch span has been in general use for cast iron pipe since 1896. It is a useful indirect test but not one of the iron in the pipe itself. Other tests have been made on specimens taken from the pipe. The most useful are the Talbot strip and full ring tests.

Talbot Strip Test. In the tests on 6-inch cast iron pipe, previously mentioned, Professor Talbot made tests on strips, $\frac{1}{2}$ inch wide, cut longitudinally from the pipe. The specimen is tested as a beam on a 10-inch span, loaded at the one-third points, (see fig. 9) with the $\frac{1}{2}$ inch dimension vertical, and with the thickness of the pipe as the width of the beam. The deflection at the center is also determined. The advantage of the Talbot strip is that it provides a test for the actual metal in the pipe and permits determining not only modulus of rupture but also modulus of elasticity.

The modulus of rupture is computed from the formula:

$$R = \frac{10P}{tK^2} \text{ lbs. per sq. in.}$$

The secant modulus of elasticity is computed from the formula:

$$E = 213\,\frac{P}{tK^3\Delta} \text{ lbs. per sq. in.}$$

in which P is the maximum load in pounds;

t is the thickness of the pipe in inches;

K is the $\frac{1}{2}$-inch dimension;

Δ is the maximum deflexion at the center in inches.

Full Ring Tests. The strength of the pipe as a ring is important because the pipe must be capable of resisting external pressures exerted by the fill over the pipe and also loads and impacts which may be transmitted through the fill to the pipe. Experiments were made on rings of various lengths cut from the pipe. It was found that short rings ($\frac{1}{2}$ to 1 inch) gave results materially higher and were not as representative of the strength of the pipe as longer rings. It has

FIG. 7. 48-inch Cast Iron Pipe Ready for Bursting Test, [illegible]

FIG. 8. 48-inch Cast Iron Pipe After Bursting Test, [illegible]

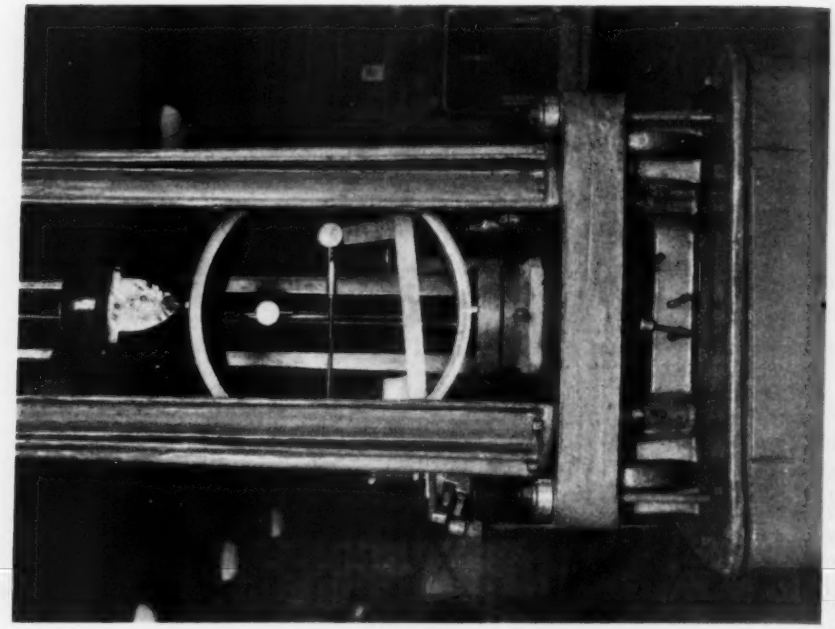


FIG. 10. Full Ring Compression Test of 20-inch Cast Iron Pipe, U. of Ill.

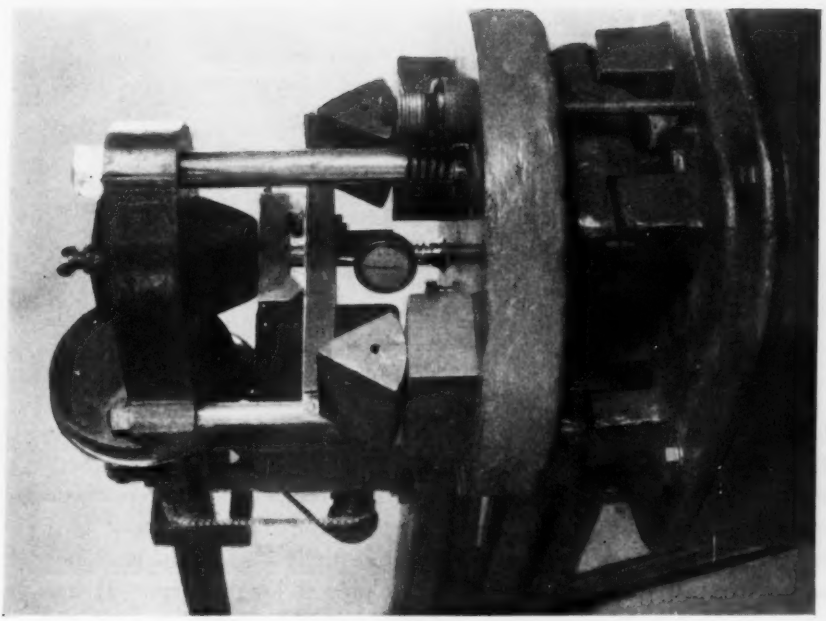


FIG. 9. Talbot Strip Test, U. of Ill., 1930

been recommended that the rings be made with lengths of one-half the diameter of the pipe but not longer than 12 inches.

The ring is placed in a testing machine (see fig. 10) and the load is applied through a bar to the top element of the ring and may be supported on a bar pressing against the lowest element, or it may be supported on two bars pressing against elements spaced symmetrically with the lowest element of the ring. The first is known as the "two-point" and the second as the "three-point" method of loading. A piece of leather, or similar material, should be inserted between the bars and the ring to distribute the load evenly. The ring should be loaded in such a way that the vertical deflection shall be the same from end to end. The spacing of the two bottom supports in the three-edge method of loading should not exceed one-fifth of the nominal diameter of the pipe. The results of the two-point and the three-point loading tests are nearly identical. The vertical deformation is measured for determinations of the modulus of elasticity. The modulus of rupture and the secant modulus of elasticity are determined from the following formulas:

$$R = 0.954 \frac{P(d + t + \Delta x)}{bt^2} \text{ lbs. per sq. in.}$$

$$E = \frac{0.225\, P(d + t + \Delta x)^3}{\Delta y b t^3} \text{ lbs. per sq. in.}$$

in which P is the ultimate load in pounds;
d is the internal diameter of the pipe in inches;
t is the thickness of the pipe in inches;
b is the length of the ring in inches;
Δy is the ultimate decrease in vertical diameter in inches;
Δx is the ultimate increase in horizontal diameter in inches.

Direct Tension Tests. Several different forms of specimens for direct tension tests were tried. The cheapest as well as the most satisfactory specimen was made from a piece 1.5 inches wide and 12 inches long cut longitudinally from the pipe. (See fig. 11.) The central portion was milled with a 2-inch cutter to a width of ½ inch, leaving a 2-inch shoulder on each end. One-half inch holes were drilled 1 inch from each end on the center line of the reduced section. The load was applied through hardened ½ inch steel pins. An extensometer with a gage length of 4 inches was used to measure the elongation.

The results of the direct tension tests are given in table 4. It

Fig. 9. Talbot Strip Test, U. of Ill., 1930

Fig. 10. Full Ring Compression Test of 20-inch Cast Iron Pipe, U. of Ill.

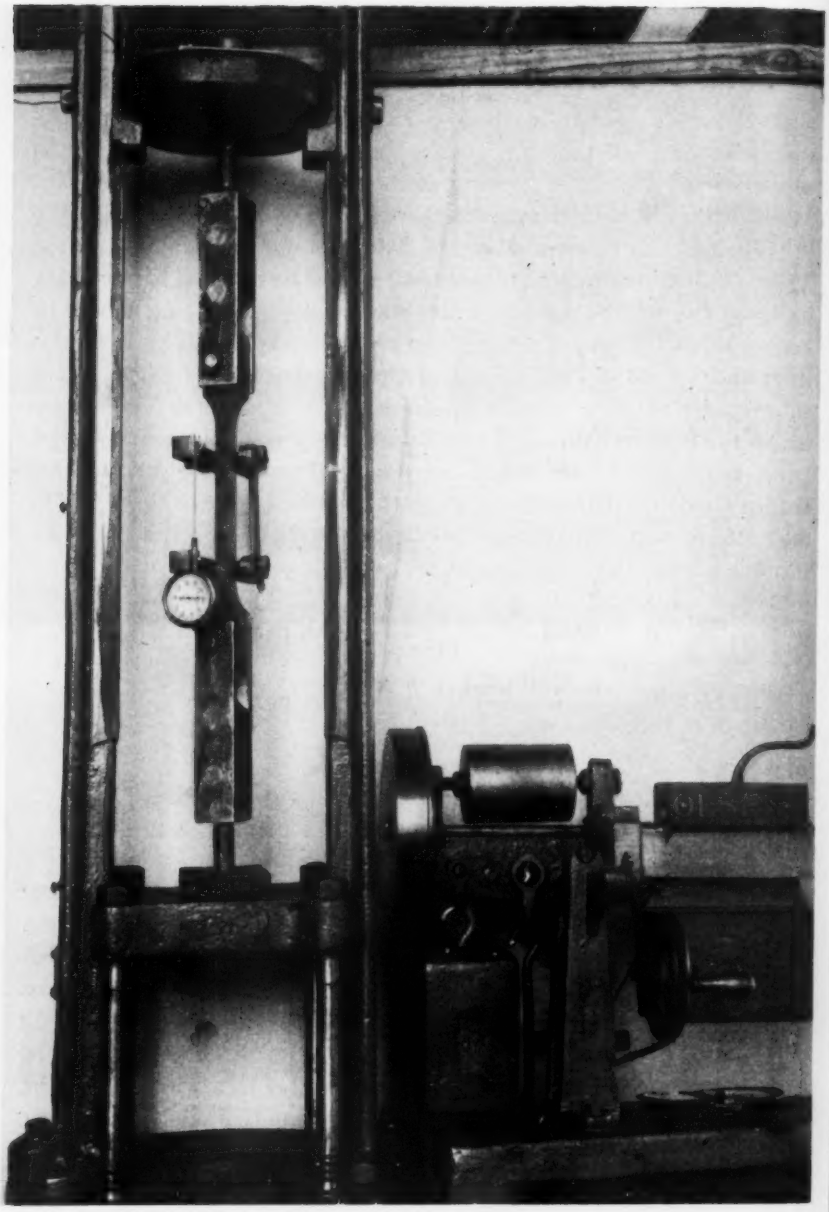


FIG. 11. Tension Test of Cast Iron, U. of Ill., 1930

will be noted that the tensile strengths determined from the bursting tests are always much lower than those from the direct tension tests.

TABLE 4

Results of Tests on Pit Cast Pipe

DIAM. AND LOT	TENSILE STRENGTH		TALBOT STRIP		FULL RING	
	Computed from Burst Pipe	Direct Tension	Mod. of Rupture	Secant Mod. of Elasticity	Mod. of Rupture	Secant Mod. of Elasticity
Talbot and Richart Tests						
	lbs./sq. in.	*lbs./sq. in.*	*lbs./sq. in.*	*lbs./sq. in.*	*lbs./sq. in.*	*lbs./sq. in.*
6-inch						
1	13,900	23,500	35,300	7,500,000	41,200	9,720,000
4	16,100	25,400	38,300	7,200,000	37,500	8,450,000
20	14,700	20,100	33,900	7,710,000	41,900	10,220,000
30	13,700	19,800	33,700	6,630,000	38,300	9,230,000
40	13,400	26,400	39,100	7,430,000	46,700	11,200,000
70	14,800		34,900	7,160,000	34,300	
71	14,600		33,500	6,870,000	36,000	
72	14,400		32,600	6,610,000	40,500	
73	16,400		34,400	7,320,000	41,800	
2	14,400	23,800	39,100		43,800	
3	15,200	31,000	42,300		48,500	
5	12,500	24,500	39,400		44,800	
Enger and Lansford Tests						
12-inch						
12	16,800	23,400	40,200	7,300,000	47,500	10,260,000
13	12,500	19,200	34,200	5,250,000	40,800	9,200,000
14	15,000	23,200	40,700	7,850,000	49,500	13,890,000
20-inch						
1	15,000	21,500	40,600	6,080,000	48,500	10,200,000
2	13,500	19,000	37,000	5,860,000	41,600	10,800,000
3	13,000	18,300	38,200	6,770,000	38,900	11,900,000
24-inch	16,600	21,200	39,200	9,900,000	35,800	13,600,000
36-inch	14,100		38,800	5,200,000		
48-inch						
35–6	14,400		35,800	5,300,000		
17	10,150	15,000	31,700	5,940,000	33,400	10,940,000

The reason for this is that all of the metal in the pipe is subjected to stress in the internal pressure test, and the failure will occur when the metal at the weakest point reaches the ultimate strength.

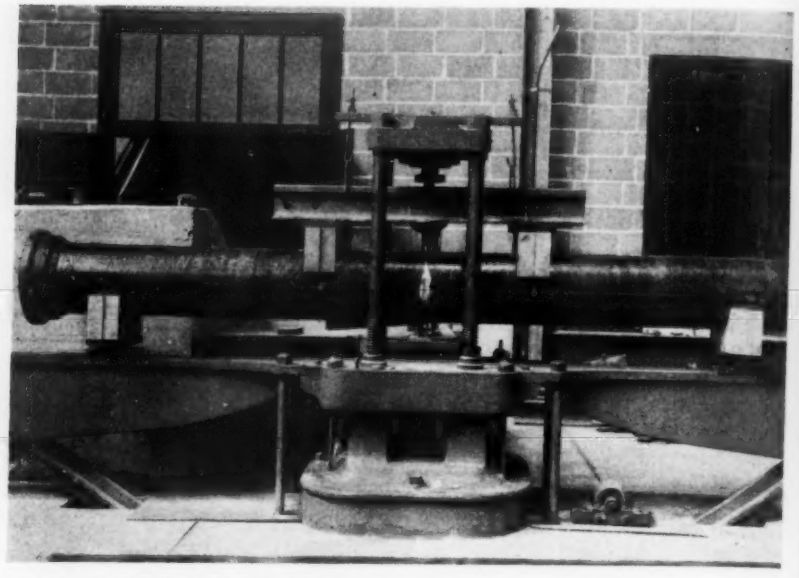


FIG. 12. 12-inch Pipe Ready for Beam Test Using Saddles, U. of Ill., 1931

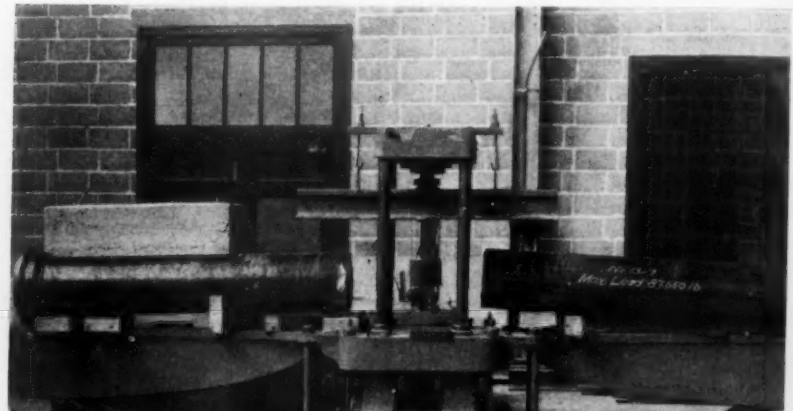


FIG. 13. 12-inch Pipe After Testing as a Beam, Using Saddles, U. of Ill., 1931

Tests of the Pipe as a Beam. Pipes in the trench are sometimes subjected to bending loads. In order to obtain information concerning the resistance which a pipe can offer to such loads, tests have been made on 6-inch pipe (by Talbot and Richart) as beams on a 10-ft. span, loaded at the center of the span, and on 12-inch and 20-inch pipe on 10-ft. spans loaded at the one-third points. The 20-inch pipe could not be made to fail as beams—the failures were always ring failures at the supports or at the loads. The 12-inch pipe could be made to fail as beams only if the reactions and the loads were applied through saddles (see figs. 12 and 13). The 6-inch pipe failed as beams in every case. The average moduli of rupture of the various lots of 6-inch pipe as beams were found to be very nearly 80 per cent of the moduli of rupture of the Talbot strips from the same lots of pipe. For 12-inch pipe as beams the corresponding ratio was only 64 per cent. The secant moduli of elasticity for the various lots found from tests of pipe as beams on 10-ft. spans were about 135 per cent of the moduli of elasticity of the Talbot strips from the same lots. The extreme variations from this value were small ($\pm$ 6 per cent) except in the case of lot 13 of the 12-inch pipe for which the ratio was 112 per cent.

Impact Tests. The ability of a cast iron pipe to withstand impact depends upon:

The quality of the metal.
The thickness of the pipe.
The diameter of the pipe.
The internal pressure.

Various impact tests were tried on cast iron pipe, or on small specimens cut from the pipe. In Talbot and Richart's tests on 6-inch pipe, the pipe was supported as a beam on rigid supports and a 50 lb. hammer was allowed to fall and strike the pipe midway between the supports. The drop of the hammer was increased in 6-inch increments until failure occurred. The pipe was filled with water under a pressure of about 50 lbs. per sq. in. and the failure was indicated by a spurt of water through the crack which was formed. In tests on 12-inch pipe a similar procedure was used except that the pipe was supported in a bed of moist sand. (See fig. 14.)

Falling ring tests were made on 6-inch, 12-inch, and 20-inch pipe. Rings one-half inch wide in tests on 6-inch pipe and one inch wide on the other pipe, were allowed to fall from increasing heights on a heavy anvil until failure occurred. The ring was turned a little each

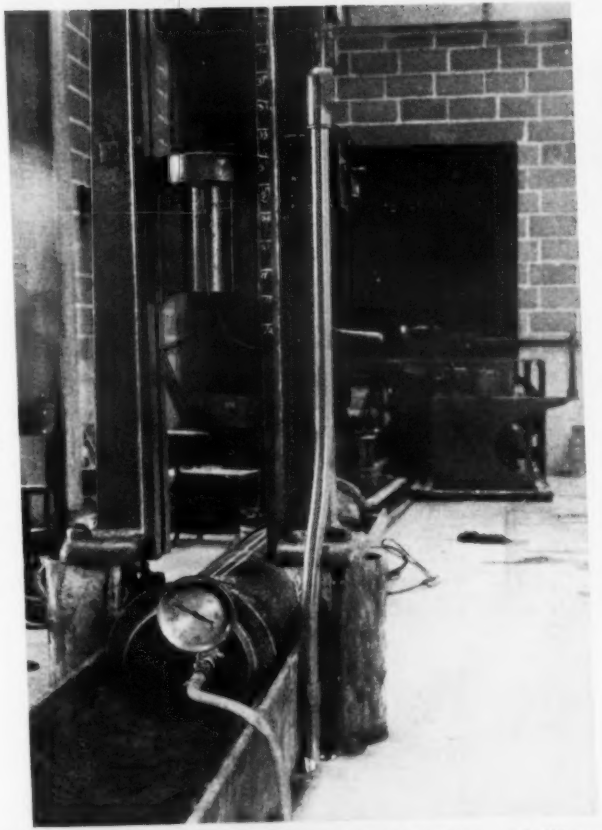


FIG. 14. Falling Weight Impact Test of 12-inch Pipe, U. of Ill., 1931

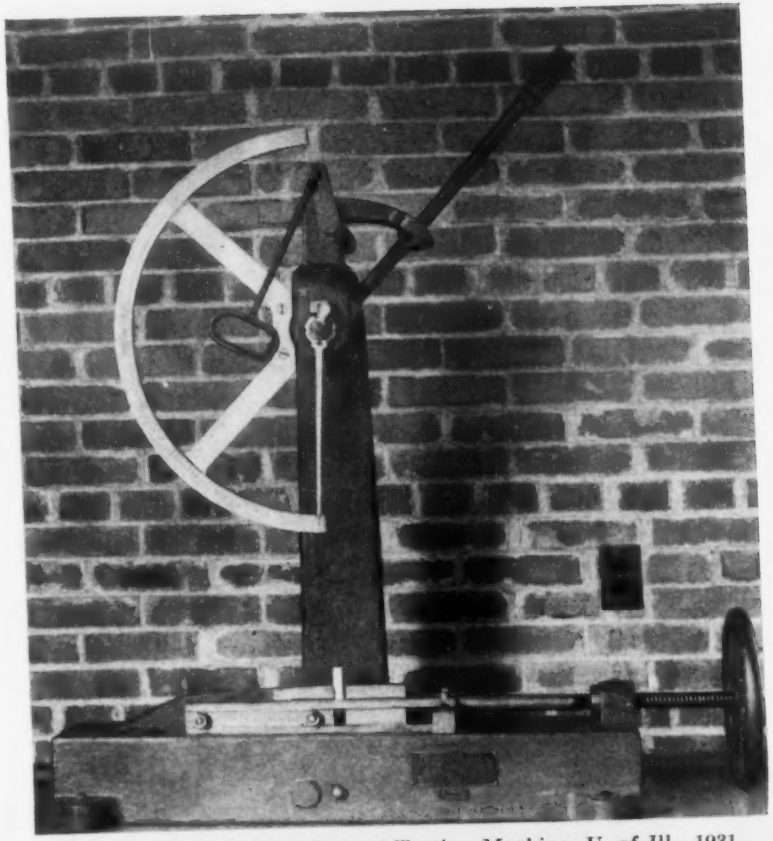


FIG. 15. Modified Izod Impact Testing Machine, U. of Ill., 1931

time to present undamaged metal to impact. The results of this test were disappointing, results being very inconsistent.

Charpy impact tests were made on material from 6-inch pipe, using both notched and unnotched specimens. The energy absorbed was so small in comparison with the capacity of the apparatus that the results were not satisfactory. A small capacity Olsen impact testing machine of the Izod type, modified to take a larger specimen, was used in later tests with fairly good results. (See fig. 15.) However, the difficulty of standardizing a machine of this type made it seem unsuited for routine testing. It was found that the resilience of the metal as determined from the Talbot strip correlated reasonably well with the results of the impact tests by the modified Izod machine and also with tests made on pipe struck with a falling hammer. Therefore limiting the maximum value of modulus of elasticity and the minimum value of the modulus of rupture insures resistance to impact.

The impact resistance of a pipe varies approximately as the thickness to the three-halves power and inversely as the cube root of the diameter. The kinetic energy (WH) of a falling hammer required to cause failure depends upon the weight of the hammer. A 50 lb. hammer does not have to fall twice as far as a 100 lb. hammer to cause failure, the sharper blow of the lighter hammer being relatively more destructive. The effect of the sharp blow seems to be relatively more destructive to thick (stiff) pipe than to thin pipe, but since only a few tests have been made, it is not possible to express the results by a formula.

The effect of the internal pressure in a pipe in reducing the impact resistance is very marked. The impact resistance depends upon the amount of metal absorbing the blow, upon the square of the available tensile strength and upon the reciprocal of the modulus of elasticity. If the metal is already subjected to a high tensile stress, the additional tensile stress available to resist impact is greatly reduced. The resistance to impact of unstressed metal is represented by its resilience, and is proportional to:

$$\frac{S_u^2}{E}$$

in which S_u is the ultimate tensile strength, and E is the modulus of elasticity.

If the metal is already stressed to, say, one-tenth of its ultimate

FIG. 15. Modified Izod Impact Testing Machine, U. of Ill., 1931

FIG. 14. Falling Weight Impact Test of 12-inch Pipe, U. of Ill., 1931

tensile strength, the available resilience to resist impact (if volume of metal absorbing the impact is unchanged) is

$$\frac{(S_u - 0.1\,S_u)^2}{E} = 0.81\,\frac{S_u^2}{E}$$

That is, its impact resistance has been decreased 19 per cent. Tests have shown that the impact resistance decreases, on account of initial stress, even more than is indicated by the rough analysis given above.

9. Estimation of Fill Loads on Pipe

The earth loads which are used in computations of thickness of barrel of pipe by the new method are obtained in the manner developed in this section of the paper.

Calculation of Fill Loads on Pipes in Ditches. Ditch conduits are defined as those completely buried in ditches excavated in comparatively solid and inert materials. The installations of cast iron water and gas pipe represent a wide range of special conditions, but the major portion of the installations will fall under this general definition. The appropriate load theory, and its development will be presented first, and then its application to a few of the more common special cases will be given.

Development of the Ditch Conduit Load Theory. The theory of the loads on pipe in ditches of ordinary, or not-too-great, width, and its application to certain special cases, is based upon research studies carried out by the Iowa Engineering Experiment Station over a period of 20 years. The original development of the load theory was first conceived by Dean Anson Marston about 1907, and utilized many of the principles of Janssen's formula for pressures in grain bins. The application of the derived formula to pipe in ditches was checked experimentally a number of times. In each of these cases the load on the pipe was actually weighed, and the values of the various soil constants determined.

The load theory was derived in response to a growing realization of the need for a reliable means for calculating the loads upon sewers and drains, or for rigid clay and concrete pipe in ditches of relatively narrow width. However, this theory, and the later studies of special cases, are equally applicable to cast iron water and gas pipes.

The Load Theory. The theory of the loads upon pipe in ditches of ordinary, or not-too-great, width (see reference 6) is based upon

the fact that the filling material is more compressible than the undisturbed soil at the sides, and so has larger relative settlements. These settlements produce frictional forces which act upward on the filling material and so transfer a portion of its weight to the undisturbed soil of the ditch sides.

The magnitude of these frictional forces, or frictional decrements, depends: (1) upon the intensity of the horizontal pressure, as expressed by "K," which is the ratio of the horizontal to the vertical pressure in the filling material (Rankine's formula), and which is dependent upon the value of μ, the coefficient of internal friction; and (2) upon the coefficient of side friction μ', between the filling material and the ditch sides. The effects of these frictional decrements are introduced into the load formula by the factor "$2K\mu'$"; it should be noted that while μ' normally is the smaller, it may equal μ, but cannot exceed it.

These upward frictional forces tend to concentrate the vertical load or pressure in the central portion of the column of filling material. Cast iron pipe normally are more rigid, or less compressible, than the columns of filling material between the pipe and the ditch sides. These considerations lead to the conclusions that the total load, at the level of the top of the pipe, comes upon the pipe, and consequently that the width factor in the load formula should be B_d, the width of the ditch at the level of the top of the pipe. The second of these assumptions may be too severe for some installations, but it is the only safe one for all installations except cases where the backfill is thoroughly tamped to the level of the top of the pipe in a ditch whose width places it in the class of "wide ditches" as discussed in a later section.

The calculation of the load normally is made with the value of C_d, the load-calculation coefficient, taken from the Computation Diagram for Loads on Ditch Conduits, fig. 16, using the general classes of soil given there as a basis for the selection. The line for values of C_d for $K\mu' = 0.1924$ gives the minimum values of C_d, and of loads; these values should not be used in normal design calculations. The line for $K\mu' = 0.110$ gives the normal maximum values of C_d and of loads; these values should be used only when it is definitely known that so low a value of $K\mu'$ is applicable. If the character of the soil is not known, the values of C_d should be those for $K\mu' = 0.130$, for the "ordinary maximum (load) for clay," and the minimum value of $K\mu'$ ordinarily encountered. In special cases,

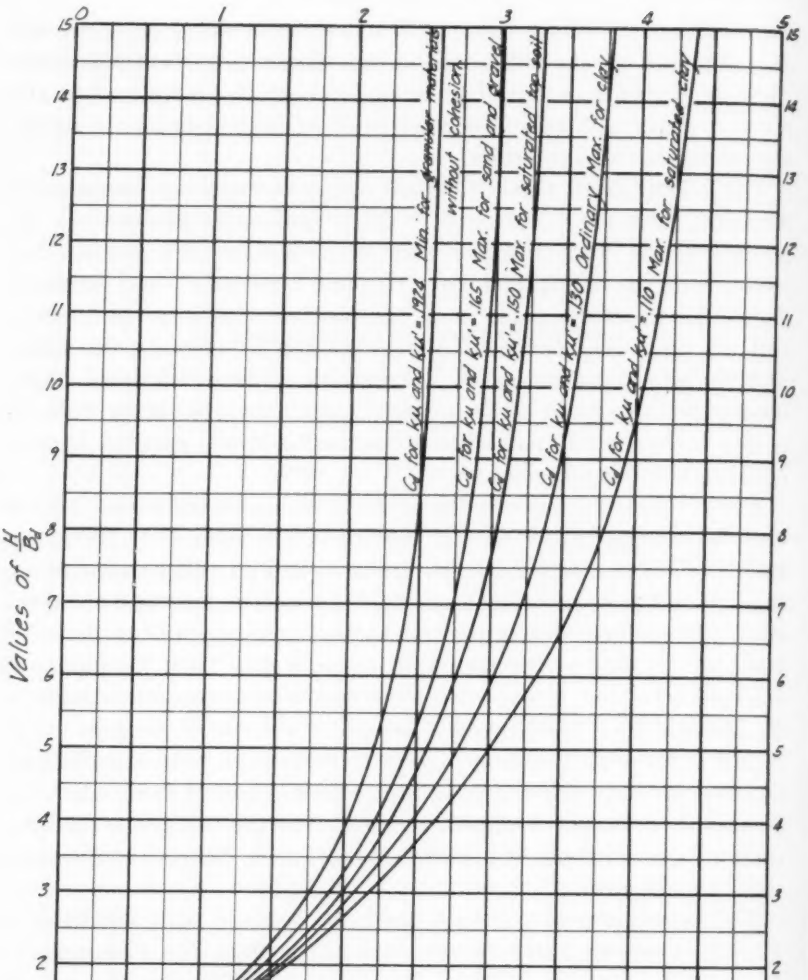

Values of $\frac{H}{B_d}$
Values of Coeficient - C_d
C_d for k_u and k_u' = .1924 Max. for granular materials without cohesion
C_d for k_u and k_u' = .165 Max. for sand and gravel
C_d for k_u and k_u' = .150 Max. for saturated top soil
C_d for k_u and k_u' = .130 Ordinary Max. for clay
C_d for k_u and k_u' = .110 Max. for saturated clay

FIG. 16. Computation Diagram for Ditch Conduits (completely buried in ditches). Load per Unit of Length, $W_c = C_d w B_d^2$ (Foot-Pound Units)

W = Unit Weight of Fill Materials.

B_d = Breadth of Ditch at the Top of Conduit.

H = Height of Fill over Top of Conduit.

it may be desirable to determine values of μ and μ', and to compute the values of C_d; such determinations and calculations are not difficult, though the latter may be found tedious unless a table of exponential values is available.

The actual value of w, the weight per cubic foot of the settled filling material, should be used whenever it is known. If the general class of soil is known, the safe, average value of the weight may be taken from the table 5. Where the class of soil is not known, the value of w should be 120, the value which normally accompanies a value of 0.130 for $K\mu'$.

The width factor, B_d, used in this load formula is the width of the ditch at the level of the top of the pipe. Since the load increases rapidly with increases in B_d (C_d varies with H/B_d and W_c with B_d^2) the value of B_d used in the load calculation should be, in general,

TABLE 5

Average Safe Working Values for Use in the Calculation of Loads on Ditch Conduits

FILL MATERIAL	w	$K\mu$ OR $K\mu'$
Loam, sandy loam	110	0.150
Sand	115	0.165
Gravel	125	0.165
Clay (ordinary maximum load)	120	0.130
Sandy or gravelly clays	120	0.140 to 150
All clays, saturated	130	0.110

the maximum width which will be used, or permitted, in the construction. The only exception to this is for "wide ditches" as explained below.

Calculations made in this way give the probable maximum loads. This calculated maximum may occur very soon after the ditch is filled, may not develop for some time, and in infrequent instances may never be experienced (7). The records of long-time research studies show that there are recurring annual or periodic maximums which approximate the actual and calculated maximums.

Sloping-sided Ditches. The load on a pipe in a ditch is not affected by the width of the ditch at levels above that of the top of the pipe (8); and therefore the load on a pipe in a sloping-sided ditch may be calculated with the ditch conduit formula if B_d is taken as the actual width at the level of the top of the pipe. The following discussion

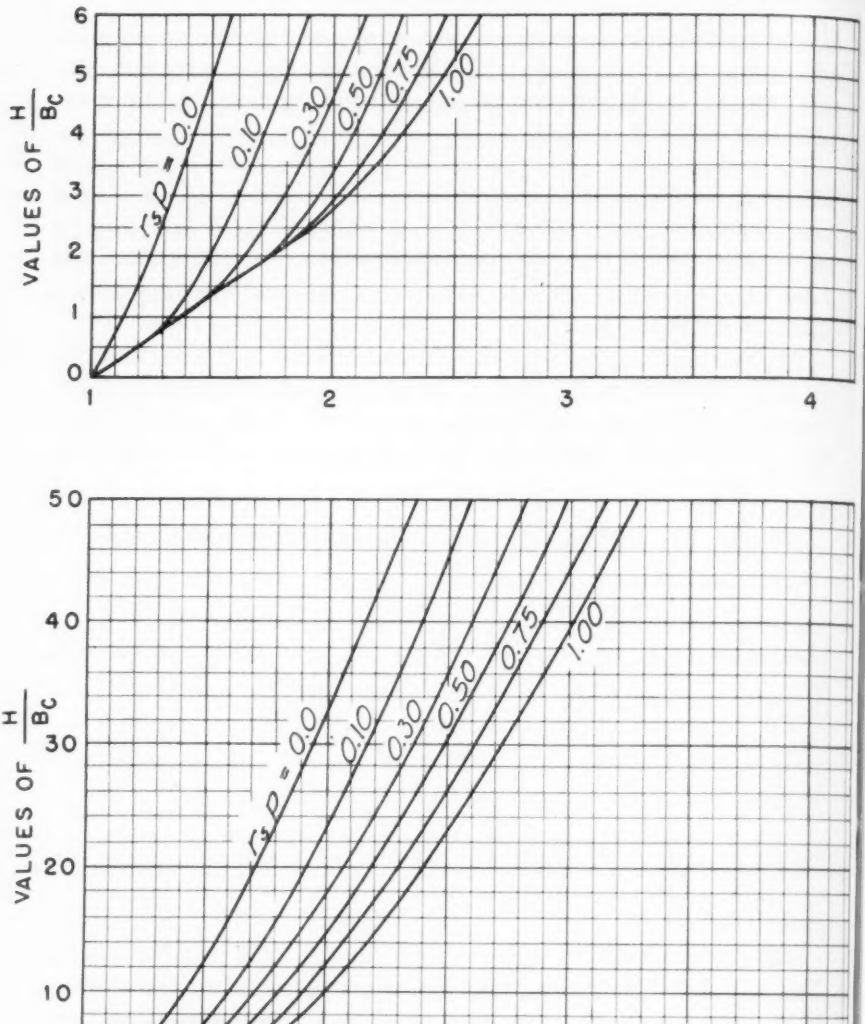


FIG. 17. Values of B_d/B_c for Ditch Conduit Loads to Equal Projecting Conduit Loads

of "wide ditches" applies to both sloping-sided and vertical-sided ditches.

Wide Ditches. Research studies (9) have shown that when the width of ditch is too great in relation to the breadth or outside diameter of the conduit, the load on the conduit is that for a projecting conduit. The values of this limiting or "transition" width (the maximum width to which the ditch conduit theory is applicable) vary primarily with those factors which determine the loads by the projecting conduit theory. For normal design calculations, values of the transition or limiting width may be taken from fig. 17; that is when the value of B_d/B_c shown by this diagram, for the appropriate values of H/B_c and r_sp, equals the ratio of the specified or assumed values of B_d and B_c, that value of B_d is the transition width. When B_d exceeds the limiting width the projecting theory applies; the loads for these cases may be calculated by the projecting conduit theory, or the indicated limiting width may be used as the B_d value in the ditch conduit load formula.

The transition widths for all commonly encountered cases of pipe laid in ditches, except for Field Condition D—pipe laid on blocks with backfill properly tamped under and around the pipe, may be taken as shown by the line for $r_sp = 0.75$ on fig. 17. The loading conditions for Field Conditions B and F would justify slightly lower values of r_sp, but the resulting decreases in fill load normally will be well under 10 per cent and so may be neglected. The loading conditions for Field Condition D will cover a range of values for r_sp from 0.10 for small pipe up to 0.75 for pipe 20 inches and larger and so the fill loads for pipe smaller than 20 inches will be sufficiently less in the case of Field Condition D to require the use of the more exact figures.

The diagrams, figs. 18 and 19, show graphically fill loads per foot of pipe of sizes 3-inch to 60-inch, for depths of cover from 2 feet to 24 feet, fig. 18 being for Field Conditions A, B, C, E and F and fig. 19 for Field Condition D. They are for a vertical-sided trench of width 2 feet greater than the nominal diameter of the pipe, which is the width of trench assumed in computing the pipe thickness schedules for Committee A-21, and have been computed in accordance with the methods described in the preceding paragraphs. The "breaks" in the load curves are at the "transition" widths: the loads to the left are those computed by the "projecting conduit" theory and those to the right by the "ditch conduit theory."

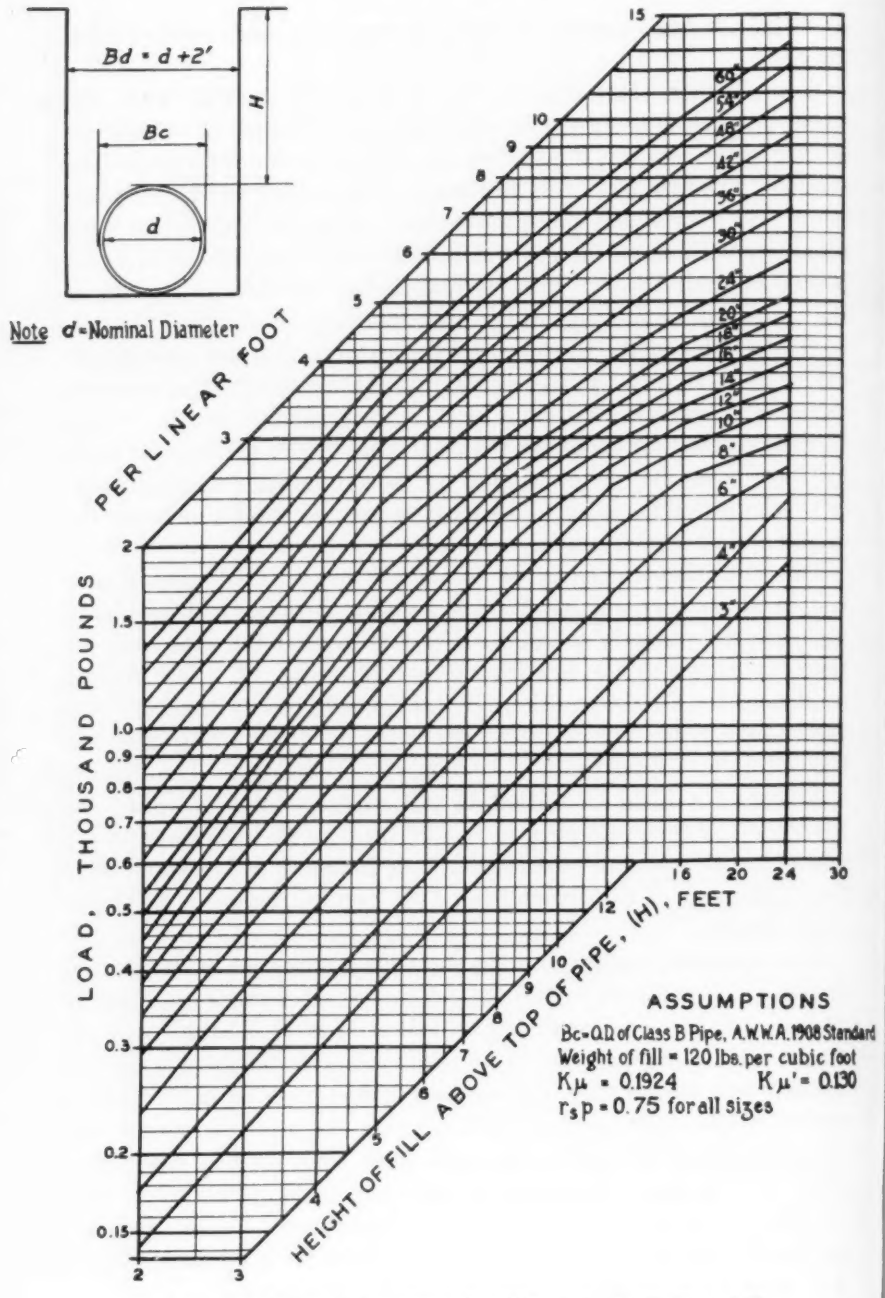

Bd = d + 2'
H
Bc
d
Note d = Nominal Diameter
LOAD, THOUSAND POUNDS PER LINEAR FOOT
HEIGHT OF FILL ABOVE TOP OF PIPE, (H), FEET
ASSUMPTIONS
Bc = O.D. of Class B Pipe, A.W.W.A. 1908 Standard
Weight of fill = 120 lbs. per cubic foot
Kμ = 0.1924 Kμ' = 0.130
r_sp = 0.75 for all sizes

FIG. 18. Earth Loads for Field Conditions A, B, C, E and F

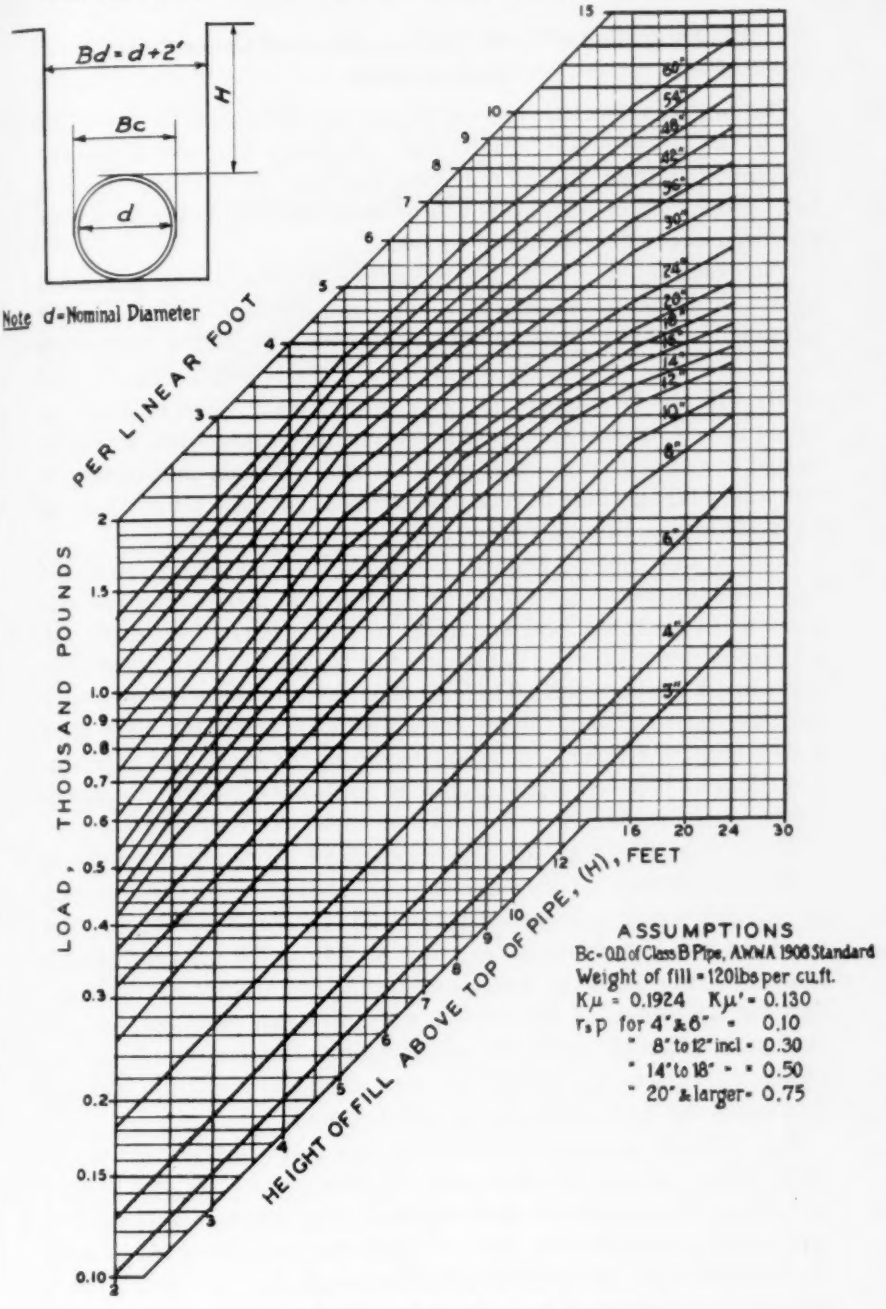


FIG. 19. Earth Loads for Field Condition D

10. Estimation of Loads Transmitted from Concentrated Surface Loads

The preceding section has explained the calculation of the loads due to the fill materials. Many cast iron mains will receive also the transmissions from static or moving loads at the surface. Such a large proportion of such loads will be those due to truck wheels that the discussion will be confined to them.

The research data and the calculation method to be presented apply to unpaved roadways. The transmissions through rigid pavements have not been studied experimentally, but it seems safe to consider that the transmissions from truck wheels on rigid pavements will not be important. Any intermediate types of surfaces, which in certain probable conditions have little structural strength, should be considered as unpaved roadways. Broken pavements, or temporary filling where pavements have been cut, also act as unpaved surfaces in transmitting surface loads.

Concentrated Surface Loads. Research (10) has shown that the total load, or pressure, received by a horizontal plane of a given size when a concentrated load is applied at the surface of an earth fill, may be calculated by the Boussinesq law for the distribution of pressures in an elastic solid. The character of the researches was such that the distribution of the pressures was not studied, but since their results show the theory to be applicable to the total load so transmitted, it is believed that the law is applicable also to the distribution of the loads.

These researches have demonstrated three other facts of interest in this connection. They have shown: (1) that a truck wheel may be considered as a true concentrated load; (2) that the load due to a moving truck wheel may be as much as 100 to 200 per cent greater than the load due to the static wheel, but that an increase of 50 per cent for the impact of the moving wheel is a safe addition; and (3) that when all other conditions are constant, the load due to a concentrated surface load will be the same when the conduit is laid in a ditch as when it is laid under an embankment.

If the receiving plane is sufficiently large, the distribution of the transmitted vertical pressure may be represented by the surface developed by revolving a witch-shaped curve about a vertical axis which passes through the point of application of the load. Figure 20 illustrates the longitudinal distribution of the transmitted load, and the combination of loads from two passing trucks. It is logical

to consider the load on short sections of pipe to be uniformly distributed in a longitudinal direction, as shown for the 3-foot length under the inside wheels.

The curves of fig. 21 have been prepared in accordance with the principles discussed above, and furnish a convenient means of determining the transmissions, per linear foot, from the rear wheels of two passing trucks.

As the area over which this load is of important intensity is comparatively short and narrow as indicated by fig. 20, it does not have as much effect on the pipe as would a uniform load extending all along the pipe and of intensity equal to the maximum intensity of the

TABLE 6

Reduction Factors for Truck Load

DIAMETER OF PIPE	PERCENTAGES OF TRUCK LOAD USED							
	2.5′–3.5′ Cov.		4′–7′ Cov.		8′–10′ Cov.		Over 10′ Cov.	
	Field Cond.							
	A, B, E & F	C & D	A, B, E & F	C & D	A, B, E & F	C & D	A, B, E & F	C & D
inches								
4 to 12	100	78	100	84	100	90	100	95
14	92	78	100	84	100	90	100	95
16	88	78	95	84	100	90	100	95
18	85	78	90	84	100	90	100	95
20	83	78	90	84	95	90	100	95
24 to 30	81	78	85	84	95	90	100	95
36 to 60	80	78	85	84	90	90	100	95

truck load. For this reason the truck load is reduced by multiplying by factors given in table 6, which have been carefully estimated to take account of the aid which the portion of the pipe, upon which the main part of the truck-load comes, receives from the adjacent parts of the pipe which are less loaded. In the case of pipe supported on blocks the truck loads are carried to blocks by the pipe acting as a beam, and the reduction factors are computed with the truck load in the most unfavorable condition, i.e. the position which gives the maximum load on a block coming from the truck load. In all cases the reduction factors are such that, when applied to the truck load per foot computed from the diagram, they will give the uniform continuous load per foot which is equal in effect to the truck load.

11. Determination of Ratios to 3-Edge Bearing

It will be recalled that the parabolic load-pressure relationship was determined experimentally with the exterior loads applied not under any of the ordinary trench conditions but through 3-edge bearings. The ratios by which estimated loads received by the pipe under the various actual trench conditions are adjusted to the 3-edge loads to which the load-pressure formula is applicable are explained below.

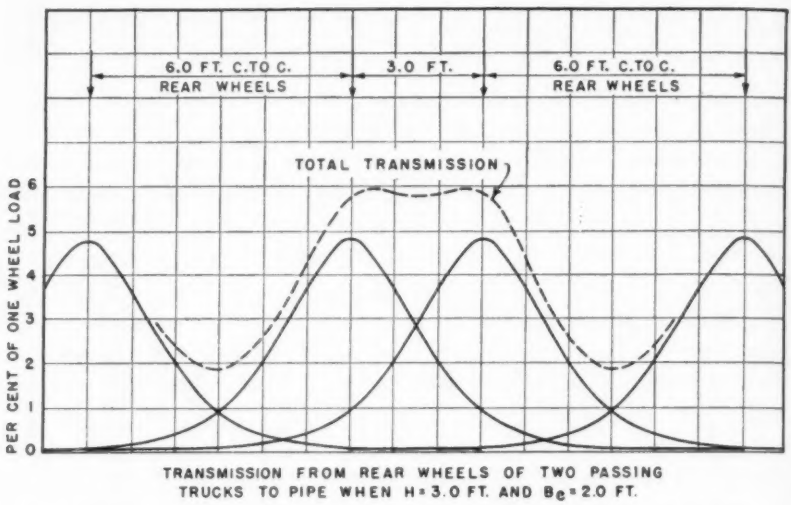


FIG. 20. Transmission from Rear Wheels of Two Passing Trucks to Pipe, when H = 3.0 ft. and B_e = 2.0 ft.

In sections 5 and 7 were explained the actions of an elastic ring under external load and internal pressure, and the fact that the crushing strengths of pipe on blocks are dependent upon some factors which do not affect the crushing strengths of pipe in earth beddings. Accordingly, the presentation of crushing strengths will be divided into two parts, and the applications of these principles made to each.

The field conditions to be studied were selected as covering the whole range of conditions normally encountered, and as being those which could be simulated satisfactorily in laboratory tests. The number of conditions, including internal pressures, which could be included in the experimental study was limited by the number of specimens and the time available for this part of the work. This

selection of the conditions to be studied was influenced also by the earlier studies of the Iowa Engineering Experiment Station of the supporting strengths of clay and concrete pipe in earth beddings; the results of these earlier studies were utilized in so far as they were

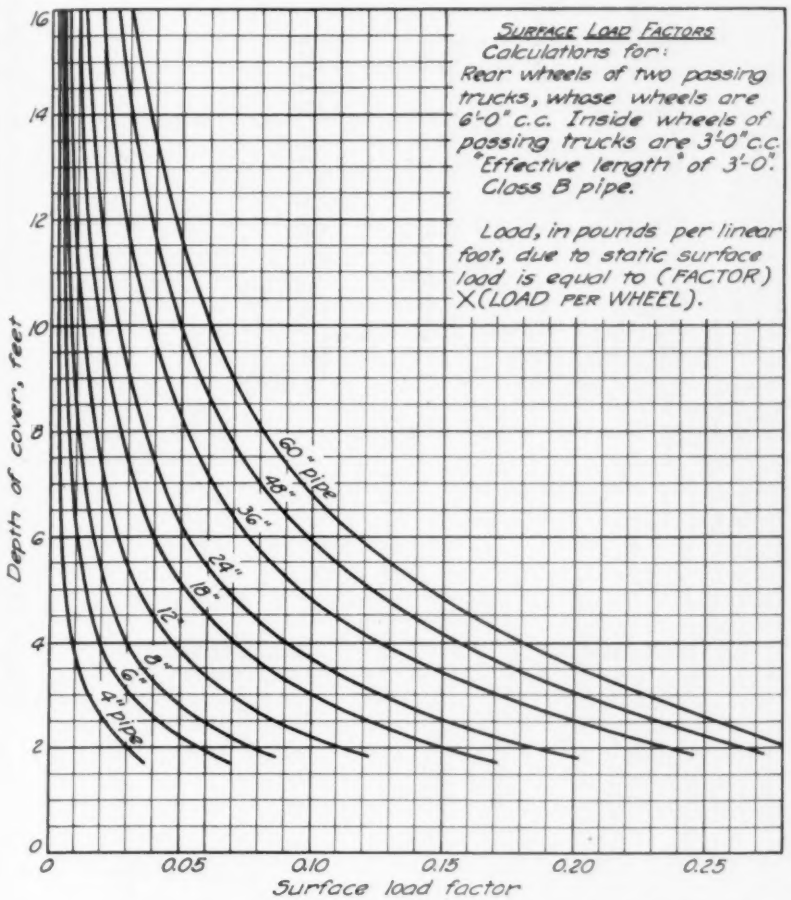
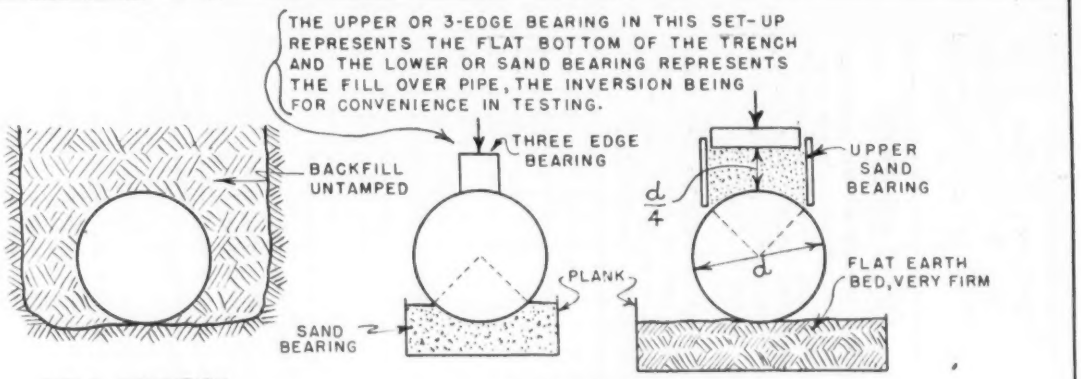


FIG. 21. Factors for Computing Superloads on Pipe from Two Passing Trucks

applicable. It should be recognized that the various field condition designations, and the ratios to 3-edge bearing, apply to conditions of support, and not necessarily to methods of pipe laying. The method of laying is only one of the factors which determine the actual con-


THE UPPER OR 3-EDGE BEARING IN THIS SET-UP REPRESENTS THE FLAT BOTTOM OF THE TRENCH AND THE LOWER OR SAND BEARING REPRESENTS THE FILL OVER PIPE, THE INVERSION BEING FOR CONVENIENCE IN TESTING.
THREE EDGE BEARING
BACKFILL UNTAMPED
UPPER SAND BEARING
d/4
d
PLANK
FLAT EARTH BED, VERY FIRM
SAND BEARING
FIELD CONDITION
TEST CONDITIONS
FIELD CONDITION A
UPPER SAND BEARING
BACKFILL FIRMLY TAMPED
FLAT EARTH BED, VERY FIRM
FIELD CONDITION
TEST CONDITION
FIELD CONDITION B

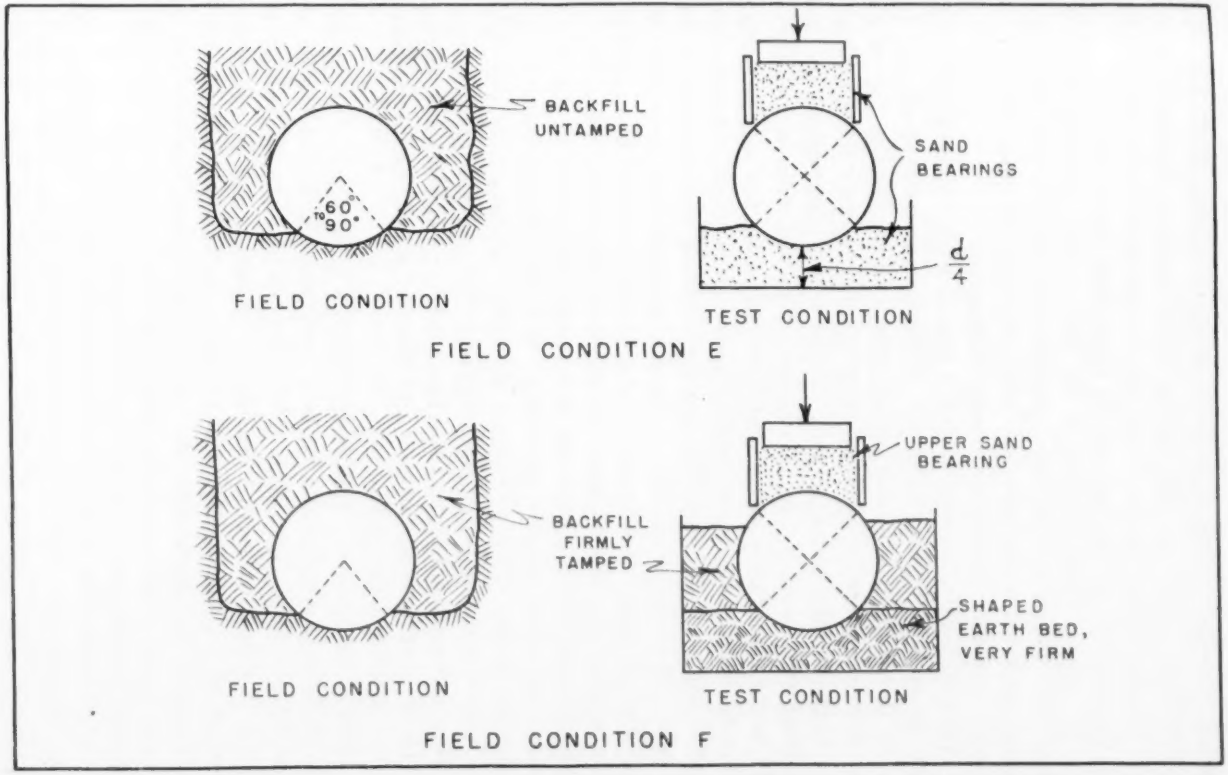


FIG. 22. Field Conditions A, B, E, and F, and Corresponding Laboratory Set-ups

dition of support. Figure 22 shows the earth-bedding field conditions selected for study, and the test methods chosen to represent them; the conditions for pipe on blocks will be described in the discussions of the ratios to 3-edge bearing for those field conditions.

The ratio to 3-edge bearing is the ratio of the crushing strength developed in a particular field condition to the strength which the same specimen would develop, with the same internal pressure, if loaded through standard three-edge bearings.

The external forces acting upon a pipe in Field Conditions A or E are assumed to be limited to the vertical load and support, and to have the same distribution for all pipe. Consequently, the ratios to 3-edge bearing for each of these conditions may have a single average, or safe, value so long as the conditions represented are defined within sufficiently close limits. Pipe laid with tamped backfill, as for Field Conditions B and F, are subjected not only to similar vertical loads, but also to horizontal forces developed through the deformations of the pipe ring and the resulting compressions of the tamped fill at the sides, and to changed support conditions if the fill be tamped under the haunches of the pipe. Since the developed lateral pressures depend upon the extent of the lateral deformation, the strength ratios for such pipe will tend to increase with the size of pipe, with their relative flexibility, and with the firmness of the tamped sidefill. The supporting strengths developed by pipe laid on blocks, with tamped or untamped backfill, depend upon the conditions indicated above, and also upon the size, character and spacing of blocks and upon the amount and distribution of any intermediate earth support between blocks.

Field Condition A. The term "Field Condition A" designates the condition for a pipe in a flat-bottomed trench in firm soil, with the backfill shovel-placed. The safe value of the strength ratio is taken as that for a settled bearing in the firmest soil in which this method of laying normally will be used. It can be shown by calculations of moments, with the elastic ring theory, that the recommended value of the strength ratio applies to a condition where the pipe is supported for about 30 degrees of its circumference.

An experimental study of a similar field condition for clay and concrete pipe (11) indicated an average supporting strength ratio, or ratio to 3-edge bearing, of about 1.20. Miller and Wise (12) have reported results which show the strengths of similar pipe with a combination of standard sand and 3-edge bearings to average 1.12 times their 3-edge strengths.

The tests of cast iron pipe under conditions to represent Field Condition A were made with the combination of sand and 3-edge

TABLE 7

Strength Ratios, or Ratios to 3-Edge Bearing, for Field Conditions A and E

(Set averages for 6-, 12- and 20-inch pipe, and individual results for 48-inch pipe)

PIPE SIZE AND CLASS	TEST TO REPRESENT FIELD CONDITION		THREE-EDGE TEST	STRENGTH RATIO
	Pressure	Load	Equivalent Load at Press. in Field Condition Test	
Field Condition A				
	lbs. per sq. in.	*lbs. per lin. ft.*	*lbs. per lin. ft.*	
20-inch, Class B	0	14,420	16,090	0.90
	0	15,530	16,090	0.96
	41	15,790	15,790	1.00
	41	13,390	15,790	0.85
	253	15,570	15,810	0.98
			Average	0.94
12-inch, Class B	0	17,940	16,700	1.07
	495	13,700	13,740	1.00
			Average	1.04
48-inch	306	21,990	14,040	1.57
	498	19,450	10,710	1.82
	0	24,520	15,920	1.54
			Average	1.64
6-inch, Class A	0	20,820	17,070	1.22
	0	23,900	16,700	1.44
	0	23,160	16,620	1.40
			Average	1.35
Field Condition E				
20-inch, Class B	530	18,390	14,260	1.29
12-inch, Class B	0	20,630	16,700	1.24
	508	20,890	13,650	1.53
			Average	1.38

bearings or with a flat, firmly tamped earth bed and an upper sand bearing (see Fig. 23). The results of these tests are given in table 7.

The tests with the 20-inch pipe were made with combination of sand and 3-edge bearings, and should show slightly lower strength

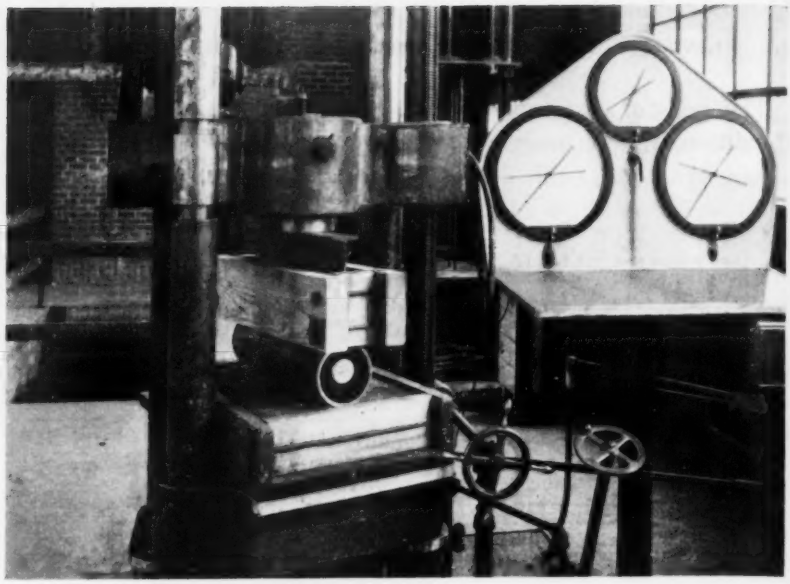


FIG. 23. Specimen of 6-inch Pipe Ready for Test on Flat Earth Bed, with Load Applied through an Upper Sand Bearing. Because of the narrow upper sand bearing "rubber gravel" was mixed with the sand.

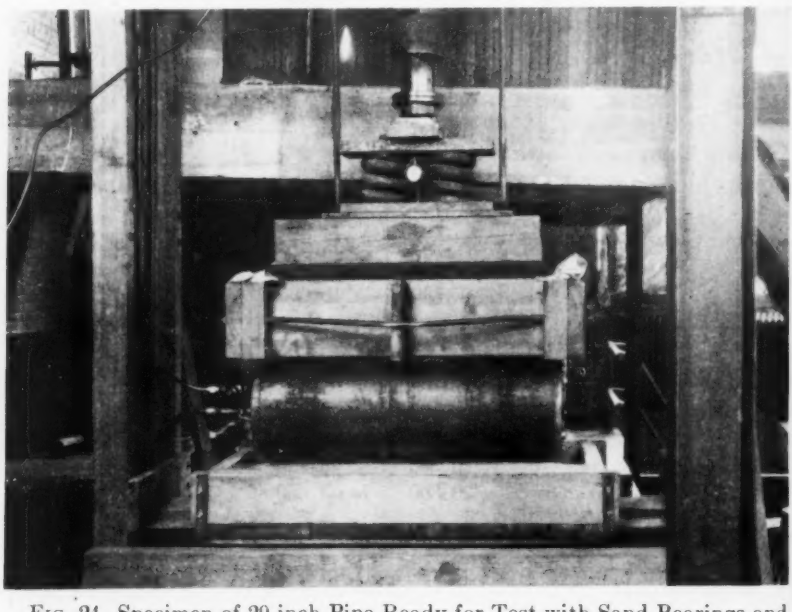


FIG. 24. Specimen of 20-inch Pipe Ready for Test with Sand Bearings and Internal Pressure. In this case the compression of the springs, as measured by the dial, was used as a measure of the applied load.

ratios than Condition A. The tests with 6-, 12- and 48-inch pipe were all made on firm, flat earth beds which probably represented the firmest soil in which this condition normally will be used. In spite of this the specimens of 6-inch pipe were pressed down into their beddings so as to provide lower bearings which were relatively wider than those for either the 12- or 48-inch pipe. The values for the 48-inch pipe appear to be high; these were based upon results for single specimens compared with individual 3-edge strengths.

Field Condition E. The earlier studies of the supporting strengths of clay and concrete pipe demonstrated that the supporting strength with standard sand bearings was the same in general as that under a field condition almost identical with Condition E, and that this strength was 1.50 times that with 3-edge bearings. Since there appeared to be little reason to suspect that these relationships would not apply to cast iron pipe, the tests to represent Condition E were made with sand bearings, and were limited to demonstrating this applicability, with different internal pressures, (see fig. 24).

The strength ratios from these tests are reported with those for condition A in table 7. It will be noted that the strength ratios range from 1.13 to 1.53, and generally are a little below the value of 1.50 recommended for clay and concrete pipe. In view of the small number of tests with cast iron pipe, it is concluded that the average value based upon the much more extensive study with clay and concrete pipe should be adopted.

Field Condition B and F. Conditions B and F are similar to conditions A and E, except for the tamped backfill. Slightly more favorable vertical support conditions, and the lateral support developed through the compression of the tamped sidefill, result in higher strength ratios.

The earlier studies with clay and concrete pipe included a condition similar to Condition E, but because of the greater flexibility of the cast iron pipe, these early results have little applicability to them, beyond indicating the limiting values for Condition E with small pipe.

The experimental studies of these two conditions were made with pipe supported on a very firm earth bed in a heavily braced wooden frame which held the firmly tamped, sand-loam backfill; the load was applied through standard sand bearings (fig. 25). The only available material for an earth bed, which would support the pipe without undue settlement, was an artificial mixture of gravel and blue-

clay firmly tamped in place. This bedding material was used for all tests under these two conditions, the bedding being loosened and retamped as frequently as necessary, and usually for each test. The ratios to 3-edge bearing determined from these tests are shown in table 8.

It will be noted that the ratios to 3-edge bearing tend to increase with pipe size. Accordingly, the data were studied by determining and plotting ratios of the increases. A smooth curve was drawn through the plotted points and the strength ratios determined from the indicated ratios. Many members of Sectional Committee A-21

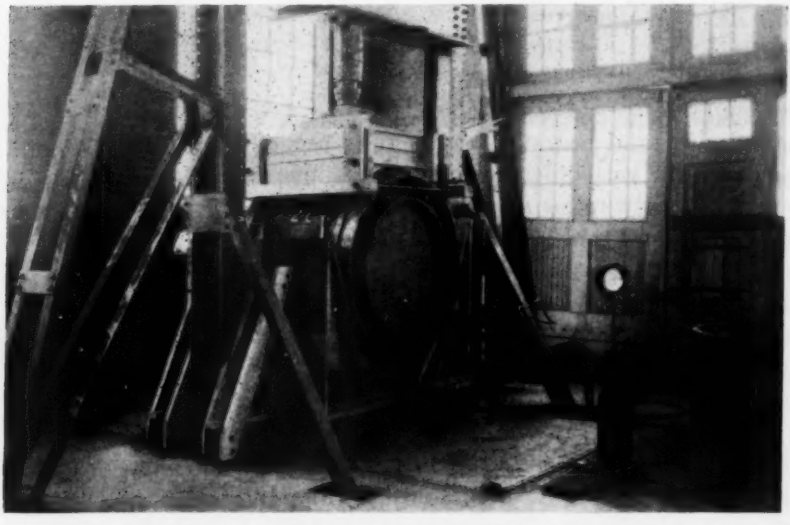


FIG. 25. Specimen of 48-inch Pipe Ready for Test with Tamped Sidefill and Internal Pressure

felt that the care used in these tests, and the firmness of the tamped backfill, were greater than could be counted upon in field installations and recommended that the increase of B over A, and of F over E, be only two-thirds that derived above. This reduction was made in the ratios which have been used in computing thickness schedules of Committee A-21 (see fig. 31).

Field Conditions C and D, Pipe on Blocks. General Considerations. The determination of safe supporting strengths of pipe on blocks must consider a wide range in loading and support conditions. An inquiry into the methods used by various communities and companies in-

dicates that blocks are used by a considerable number and that these blocks are of various dimensions. In some pipe systems the blocks are of hard, unyielding wood and blocks of generous area and thickness are not uncommon. Certain gas companies place the blocks in depressions so that their tops are flush or nearly flush with the

TABLE 8

Strength Ratios or Ratios to 3-Edge Bearing for Field Conditions B and F
(Set averages for 12-inch and 20-inch pipe and individual results for 48-inch pipe)

PIPE SIZE AND CLASS	TEST TO REPRESENT FIELD CONDITION		THREE-EDGE TEST	STRENGTH RATIO
	Pressure	Load	Equivalent Load at Press. in Field Condition Test	
	Field Condition B			
	lbs. per sq. in.	*lbs. per lin. ft.*	*lbs. per lin. ft.*	
20-inch, B	543	27,730	14,100	1.98
12-inch, B	478	20,790	13,850	1.50
48-inch	311	30,400	13,930	2.18
"	546	31,390	8,790	3.57
"	0	31,980	15,920	2.01
			Average	2.59
	Field Condition F			
20-inch, B	778	21,740	10,970	1.98
12-inch, B	502	25,780	13,690	1.88

Ratios showing effect of tamped backfill:

Conditions B and A	Conditions F and E
20-inch, 1.98:0.94 = 2.11	20-inch, 1.98:1.29 = 1.53
12-inch, 1.50:1.04 = 1.44	12-inch, 1.88:1.38 = 1.36
48-inch, 2.59:1.64 = 1.58	

bottom of the trench. In some systems single blocks are placed back of the bells in pipe lines of small diameter.

Substantial wedges are used in some cases. These were found by the Committee's tests to reduce the stress on the pipe by forming a sort of saddle which however would be of uncertain durability on account of the susceptibility of the comparatively thin wedge to the softening effect of moisture and rot.

The care in tamping which tends to produce condition D is variable

so that any condition may be met with between a severe C condition with unyielding blocks and no tamping and a well tamped D condition with depressed blocks and perhaps with substantial wedges added.

The C condition which has been studied experimentally for Committee A-21 and for which the ratios to 3-edge bearing are given is a severe condition with blocks of firm wood without wedges and without backfill support. The D strength ratio has been investigated under more varied conditions and the ratios to 3-edge bearing given are estimated to be for average conditions.

Action of pipe on blocks—Field Condition C. A continuous line of pipe supported on blocks acts as a continuous beam with hinges (the joints) which transmit shear but not moment. Actually the joints in a pipe line do transmit some moment, but its magnitude is relatively small and uncertain. The load is considered to be uniform longitudinally, so that the reactions, or the support at the blocks, are dependent upon the settlements at the blocks. Calculations and consideration of probable settlements, indicate that the only safe design basis is that of no relative block settlement and equal reactions, or concentrations, at each block. This makes it possible to determine either the critical block concentration for pipe which fail as rings or the maximum longitudinal moment for pipe which are weaker as beams.

With two blocks per 12-foot length, pipes 8 inches or more in diameter generally will fail as rings over the blocks, while 4-inch pipe will fail as beams. Tests of some Class A 6-inch pit-cast pipe showed the same strength ratios for ring and beam failures.

The deformations of a pipe supported on blocks produces a complex distribution of stresses. However, a given pipe actually supported on blocks of a given character and size will fail whenever the block concentration reaches the critical value, irrespective of the conditions which produce this block concentration. In some pipe, particularly those of large diameter and high flexibility, the greater stiffness of the hub causes it to receive additional load because of the deformation-restraint it affords both the barrel adjacent to it and the inserted spigot section.

Although failure and settlement of blocks, size of blocks and deflection of the pipe as a beam may change the block concentration, it is believed that the test data and analyses indicate safe values of the strength ratio for all sizes of pipe in condition C.

Field Condition D. Pipe in Field Condition D—laid on blocks, with the backfill firmly tamped under and around the pipe—are subject to forces and actions similar in some degree to those supported as in Field Condition C, but with the effect of such actions complicated by others resulting from vertical and lateral support from the tamped filling material. Pipe 20 inches and more in diameter are so stiff as beams that deflection can have but a minor effect upon the support conditions. For these, the lateral support developed through

FIG. 26. A Jointed Specimen of 20-inch Pipe after Loading to Represent Condition C. Note the break over the hub block under the full-length pipe.

deformation of the pipe furnishes the principal increase in supporting strength, though any settlement or compression of the blocks is also an aid. As the pipe decrease in size, their beam deflections become larger, with resulting increases in the amount of vertical support on the tamped fill. On the other hand the ring deformations decrease, with corresponding decreases in the amounts of lateral support. The resulting forces and actions are so complicated that theoretical analyses can do little more than furnish guides, and safe strength ratios have to be based upon test data. As a result it is possible so

far to recommend safe strength ratios only for pipe 20 inches and larger in size.[5]

Experimental Studies of Pipe Supported on Blocks. The experimental studies of this phase were a progressive development, both as to testing procedure and the particular problems studied. They have included:

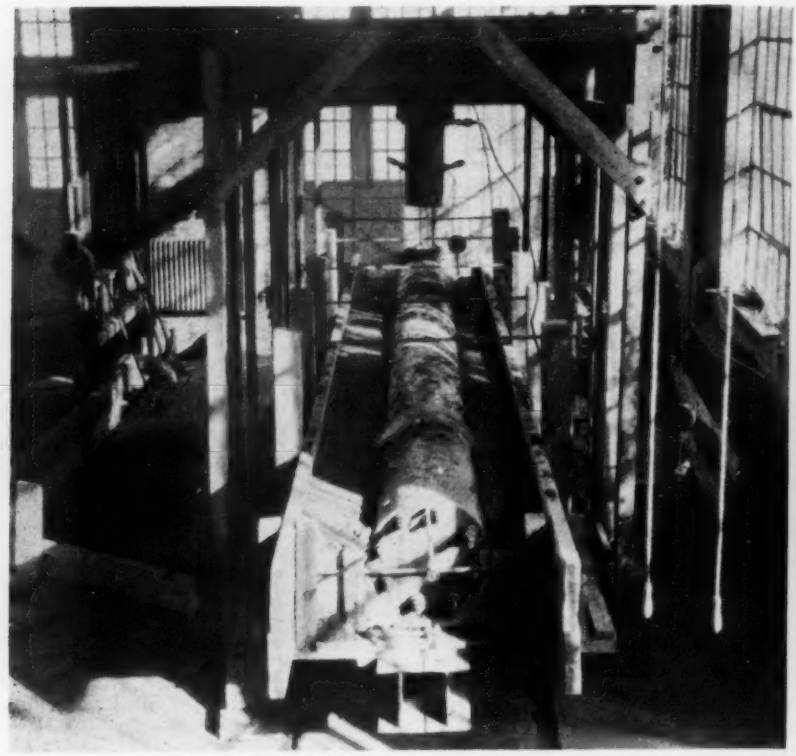


FIG. 27. The Backfill Tamped Around a 20-foot Jointed Specimen of 20-inch Pipe. Due to inclement weather the loading frame was moved indoors.

1. Tests of 20-foot jointed lengths of 20-inch pipe with internal pressures, with and without tamped backfill (figs. 26 and 27).

[5] Since the original presentation of this paper in April, 1938 a fairly exhaustive set of tests has been made for 6-inch pipe using 12-foot lengths of Class A pipe, and the D ratios for pipes smaller than 20 inches have been fixed with the aid of this new data.

2. Tests of single lengths of 12-inch pipe, 12 and 16 feet long without backfill. Figure 28 shows a typical failure at a block.

3. Tests of 4- and 8-foot lengths of 48-inch pipe, without either internal pressure or backfill.

4. Studies of the distributions of deformations of single and jointed specimens of 12-, 20-, 36-, and 48-inch, both in Illinois and Iowa laboratories. Figure 29 illustrates the transmission of extra load to the stiffer hub.

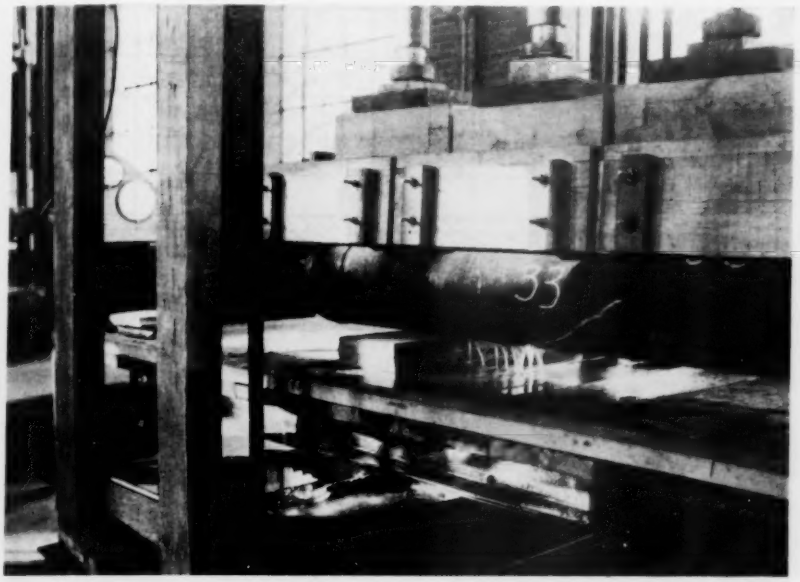


FIG. 28. The Failure of a Single Length of 12-inch Pipe Supported Wholly on Blocks. The failure appeared to start as a longitudinal crack, and often extended diagonally upward in the long span.

5. Tests of 24-foot jointed lengths of 6-inch pipe in a set-up which provided uniform distribution of load and means for determining concentration or reaction at each block (fig. 30).

Ratios to 3-Edge Bearing Adopted for Committee A-21. The ratios to 3-edge bearing which have been adopted for Committee A-21 are shown graphically and by table on fig. 31. As will be evident from the foregoing explanations they are compounded of theory and experiment. In the cases of Field Conditions C and D, especially, they have been the subject of innumerable letters and discussions.

It is not thought that they are exact nor that future experiments may not modify and improve them. A scrutiny of the computed

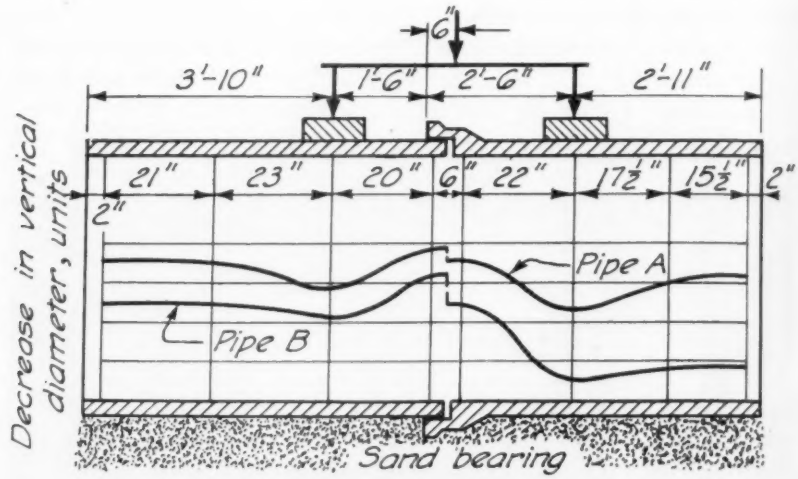


FIG. 29. Showing Excess Stiffness of Pipe at Bells

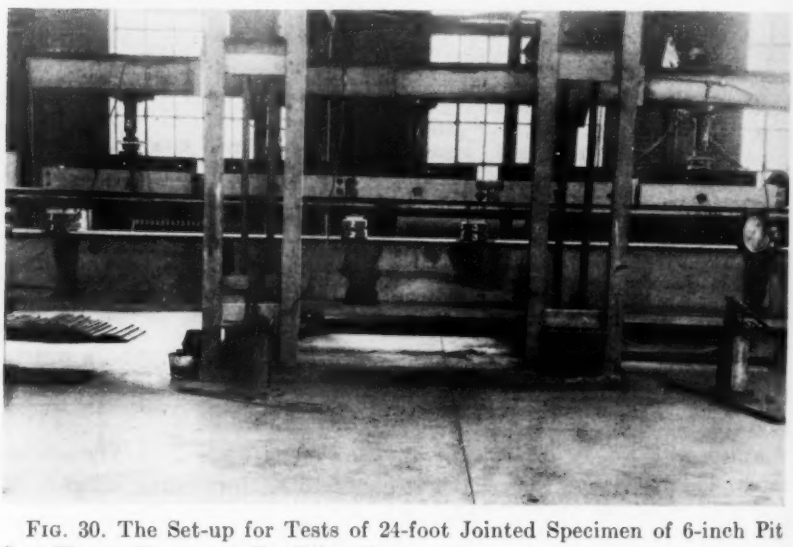


FIG. 30. The Set-up for Tests of 24-foot Jointed Specimen of 6-inch Pit Cast Pipe to Represent Condition C.

pipe-thickness tables will show that considerable modifications will not materially alter computed thicknesses and the present accuracy

of the ratios is believed to be sufficient for practical purposes and will most certainly result in rational and consistent determinations of pipe thicknesses for the various Field Conditions included in the study.

As has been explained in a foregoing part of this Section under the heading *Field Condition B and F*, the benefit in strength estimated under laboratory conditions as resulting from tamping in Field Conditions B, D and F as compared with Field Conditions A, C and E were discounted 33 per cent in fixing the ratios for use given on fig. 31 on account of expected less efficiency in field tamping as compared with that in the laboratory.

The studies for ratios do not include the field condition of pipe laid in the open, either on flat ground or partly or wholly buried and then covered with an embankment. Such conditions are to be found in dams and embankments. They are being further considered by Committee A-21.

12. Discussion of Water Hammer Assumptions

The additions to static pressure proposed to be made for water hammer are the same as those selected by Dexter Brackett previous to 1895. They have already been listed and it will be recalled that they ran from 120 lbs. for small pipe down to 70 lbs. for large pipe.

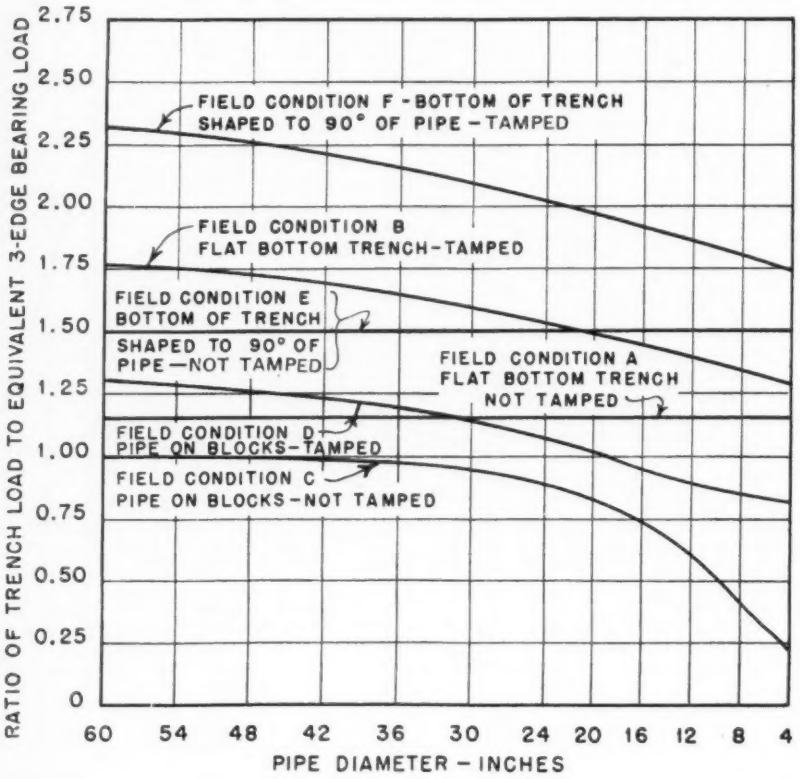
It is recognized that these allowances are based on little real information. Though water hammer has been actively investigated for several decades and not a few professors and engineers are able to solve mathematically definite problems in water hammer, there is still no body of measurements by which to estimate water hammer in the ordinary water works system.

Mr. Brackett's downward gradation in intensity of water hammer with increased diameter was based on the fact that small valves could be and were more often operated quickly than were large ones. Electric operation of pumps and their quick starting and stopping with check valve slamming were not then common, since steam power was generally used. Modern controlled check valves such as the cone valve were unknown, but large pumps were started and stopped slowly. Large breaks were observed to give large water hammers.

We shall have to admit that allowances for water hammer are not well founded owing to the fact that water works men have never seriously tried to collect data on the subject. The ordinary pressure recording gage is not to be relied upon to record the true pressure at the peak of the water hammer, though it may do so where the pipe

Erratum

The figure below is a corrected graph which should be substituted for (pasted over) the erroneous graph which appeared on page 896 of the May, 1939, JOURNAL.


RATIO OF TRENCH LOAD TO EQUIVALENT 3-EDGE BEARING LOAD
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
FIELD CONDITION F - BOTTOM OF TRENCH SHAPED TO 90° OF PIPE - TAMPED
FIELD CONDITION B FLAT BOTTOM TRENCH - TAMPED
FIELD CONDITION E BOTTOM OF TRENCH SHAPED TO 90° OF PIPE - NOT TAMPED
FIELD CONDITION A FLAT BOTTOM TRENCH NOT TAMPED
FIELD CONDITION D PIPE ON BLOCKS - TAMPED
FIELD CONDITION C PIPE ON BLOCKS - NOT TAMPED
60 54 48 42 36 30 24 20 16 12 8 4
PIPE DIAMETER - INCHES

hammer. One of the authors has noted water hammers up to 50 pounds near well pumps which are started and stopped automatically.

Hydraulic machinery at manufacturing plants has been observed to make water hammers of several hundred pounds, but these are outside the scope of ordinary water works. Separation and reunion of the water column in force mains where laid near the hydraulic gradient have caused destructive shocks, probably much greater than the Dexter Brackett allowances.

13. Details of Applying the Proposed Method with Sample Computations

In previous pages the principles involved in the new method have been explained; it remains to describe the practical mechanism by which thicknesses are computed conveniently and quickly. Rules have been written and used extensively by Sectional Committee A-21. They are given in abbreviated form below and will appear in a manual accompanying the specifications for cast iron pipe.

Figure 1 shows the load-pressure relationship previously explained and now to be used in design. A convenient form of equation of the load-pressure curve is as follows:

$$w = \frac{W}{\sqrt{P}}\sqrt{P - p}$$

where, W is the load per foot in 3-edge bearing which will break the pipe without internal pressure, computed by the formula

$$W = \frac{Rt^2}{.0795(d + t)}$$

which is a transposition of the formula given in Section 7.

P is the internal pressure which will burst the pipe without the aid of any crushing load, computed from the cylinder formula $P = \frac{2St}{d}$. (See Section 7 for explanation.)

p and w are any corresponding internal pressure and trench load which acting together will just break the pipe.

By use of the formula after W and P have been computed the curve may be drawn. Also without any formula, knowing that the curve is a parabola, the curve may be drawn by using P and W and the fractional abscissae ($\frac{1}{16}$ P, $\frac{1}{4}$ P and $\frac{9}{16}$ P) and ordinates shown in fig. 32.

The easiest approach is to assume a number of thicknesses varying by $\frac{1}{10}$ inch and draw a load-pressure curve for each thickness, using the same axes of coördinates for all. Then plot on the same diagram the p and w for the given water pressure and earth load including water hammer or truck load, whichever gives the most severe test

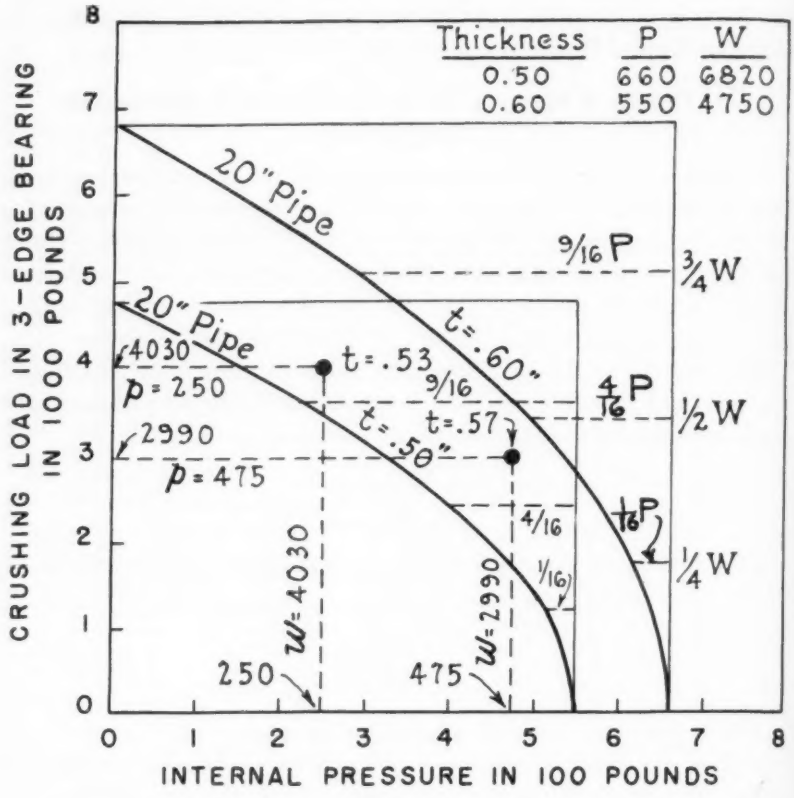


FIG. 32. Design of Cast Iron Pipe by Load-Pressure Curves; breaking strengths, 11,000-31,000

of the pipe, or trying both combinations separately in case of doubt. The occurence of water hammer and truck load simultaneously is regarded as too remote a chance to which to give practical weight. To obtain the p and w to be plotted, total water pressure and trench load are each to be multiplied by the assumed factor of safety and the trench load divided by the ratio to 3-edge bearing which is

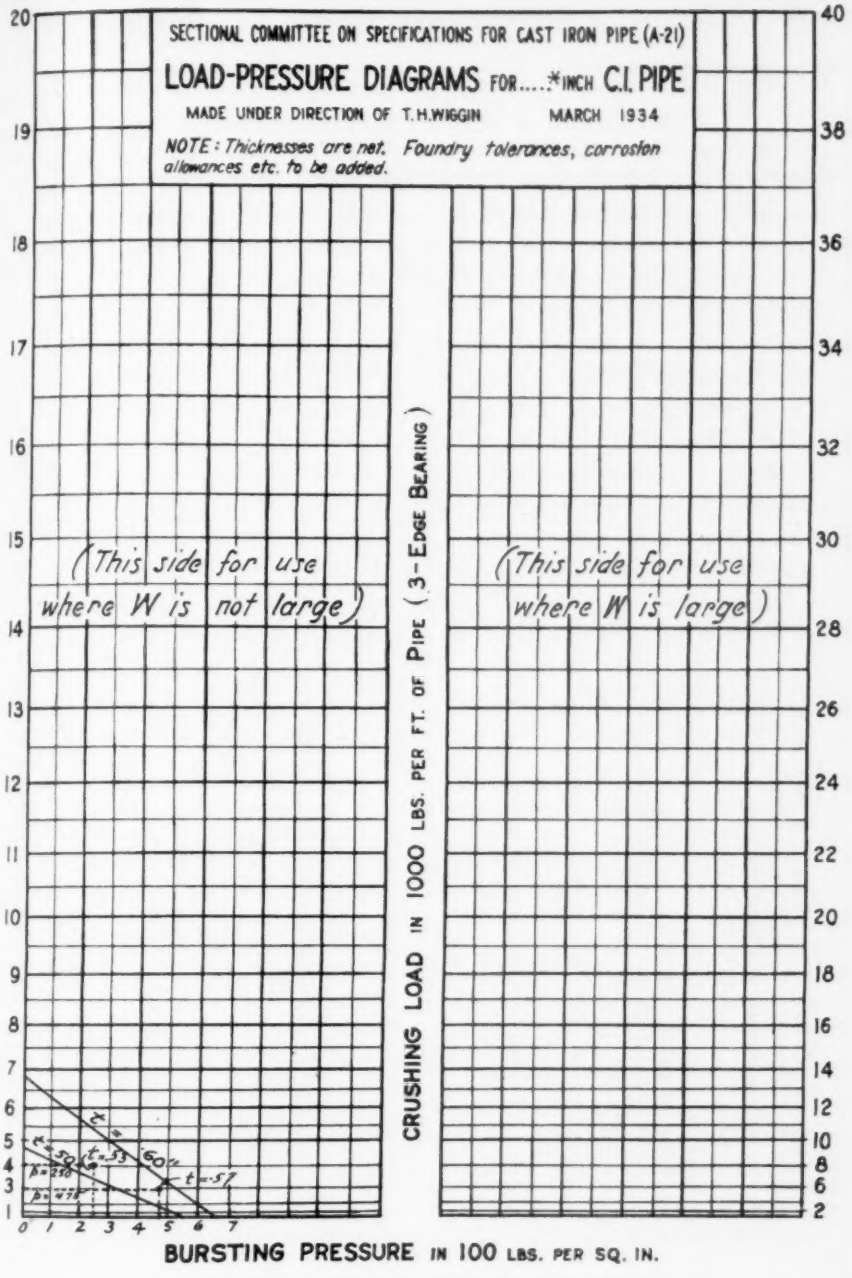


FIG. 33. Load-Pressure Diagram

(The diagram is applicable to any size of pipe. In this case it is used for a 20-inch pipe.)

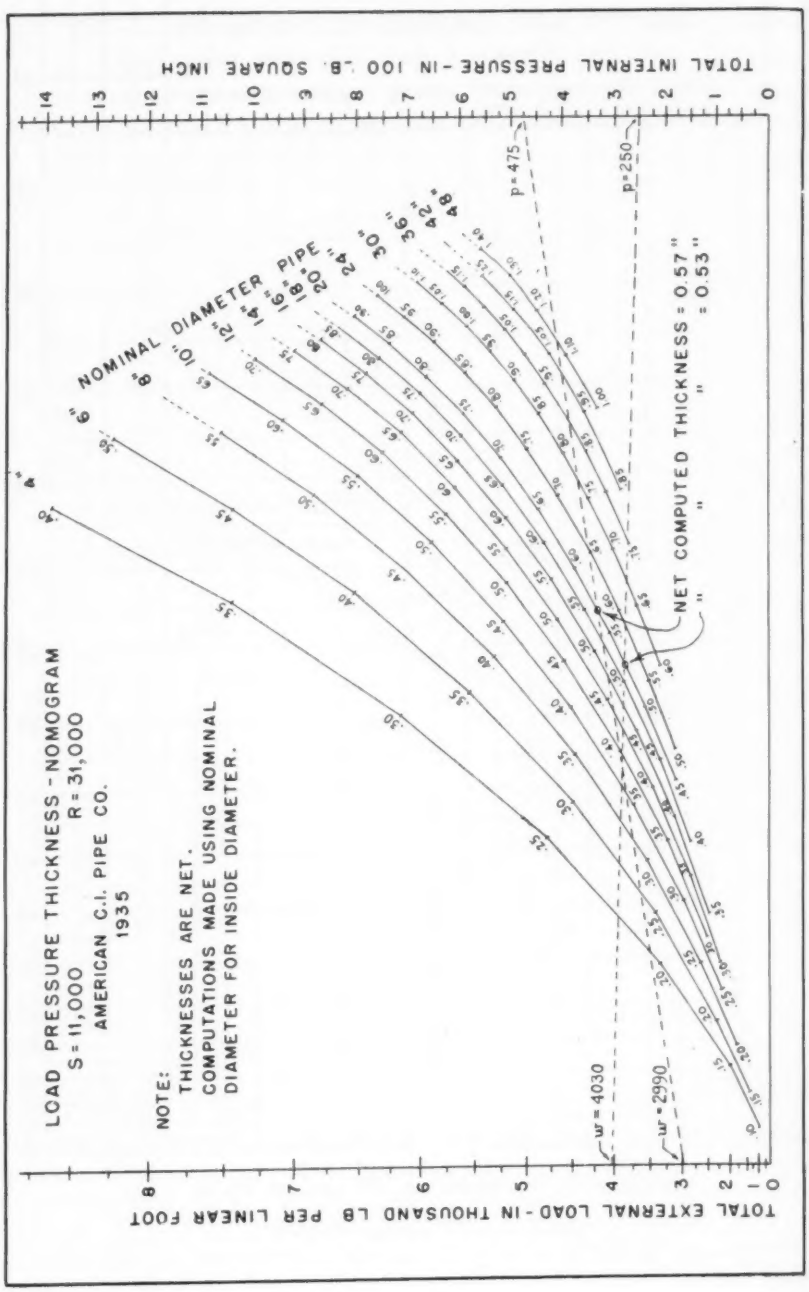

LOAD PRESSURE THICKNESS - NOMOGRAM
S = 11,000 R = 31,000
AMERICAN C.I. PIPE CO.
1935
NOTE:
THICKNESSES ARE NET.
COMPUTATIONS MADE USING NOMINAL DIAMETER FOR INSIDE DIAMETER.
NOMINAL DIAMETER PIPE
NET COMPUTED THICKNESS = 0.57"
" " = 0.53"
p = 475
p = 250
w = 4030
w = 2990
TOTAL EXTERNAL LOAD - IN THOUSAND LB PER LINEAR FOOT
TOTAL INTERNAL PRESSURE - IN 100 LB. SQUARE INCH

FIG. 34. Load-Pressure Thickness Nomogram (Acipco)

applicable to the particular method of laying, i.e. one of the methods A to F.

The plotted point will fall between the curves of load-pressure for various assumed thicknesses and the required thickness is obtained by interpolation. To this thickness must be added foundry tolerance and allowance for corrosion.

Mr. H. Victor and Mr. S. P. Owen, assisting Mr. Wiggin on pipe thickness computations, devised a method by which the parabola showing the load-pressure relationship becomes a straight line. This is done by plotting the crushing loads on a scale of squares, the internal pressures being plotted on a simple, arithmetical scale as before. A diagram shown as fig. 33 was developed under Mr. Wiggin's direction and used extensively in committee work.

The American Cast Iron Pipe Company made a further advance of inestimable value by developing a nomograph, fig. 34, by means of which and the use of a straight edge, thicknesses required for any p and w may be read directly. The nomograph is constructed for one set of values for breaking stresses, and a different nomograph is required if either of these basic units is changed.

A concrete example of the application of the method will now be given and figs. 32, 33 and 34 will be used to illustrate the process.

The example:

20-inch pit cast pipe; 100 lbs. static pressure; 90 lbs. water hammer; 5 feet earth cover; laying condition B, i.e. flat bottom trench and tamped backfill; factor of safety 2.5; tensile strength in bursting, S, 11,000 p.s.i.; modulus of rupture, R, in crushing as a ring, 31,000 p.s.i.

From the diagram, fig. 18, trench load per lin. ft.		1,760 lbs.[6]
From the diagram, fig. 21, truck load = .05 × 9,000	450	
Add 50 per cent for impact	225	
	675	
Factor for reducing truck load .90, (table 6) net truck load .90 × 675		610
Total exterior load		2,370 lbs.

Case 1. Water hammer used but no truck load.

The pipe is to be designed so that it will just break at a water pressure of 2.5 × (100 + 90) = 475 and a crushing load of 2.5 × 1,760 = 4,400 lbs. per lin. ft.

[6] Reads 1,780 on fig. 18—Original figures from a previous diagram. Difference not material.

FIG. 34. Load-Pressure Thickness Nomogram (Acipco)

Case 2. Truck load but no water hammer.

The pipe is to be designed so that it will just break at a water pressure of $2.5 \times 100 = 250$ and a crushing load of $2.5 \times (1{,}760 + 610) = 5{,}925$ lbs. per lin. ft.

The crushing loads are to be reduced before use of the diagrams because the B condition is less severe on the pipe than the 3-edge bearing condition for which the formulae and diagrams are designed. From the diagram, fig. 31, the ratio between 3-edge bearing and B effects for 20-inch pipe is 1.47. Dividing the crushing loads by 1.47 gives the figures needed and the results for use in the formula and diagrams are as follows:

	Case 1	*Case 2*
Internal pressure, p	475	250
Crushing load, w	2,990	4,030

We will next consider the construction of the diagrams upon which the above values of p and w are to be plotted in order to find the required thickness by interpolation. The diagrams in which the load-pressure lines for several assumed thicknesses of pipe are plotted have been described above as of two kinds, one in which these lines are plotted to natural scale and are parabolas, and the other in which by use of a scale of squares for the crushing loads the lines are straight. In either case only two figures are needed for each curve, viz. the crushing load, W, with no internal pressure and the other the bursting pressure P with no crushing load. In the example above it is known that the computed thicknesses will be between 0.50 inch and 0.60 inch, so that only those load-pressure lines need be drawn.

$$\text{For } t = .50 \quad P = \frac{2 \times 11000 \times .50}{20} = 550$$

$$t = .60 \quad P = \frac{2 \times 11000 \times .60}{20} = 660$$

$$\text{For } t = .50 \quad W = \frac{31000 \times \overline{0.50}^2}{.0795 \times 20.5} = 4750$$

$$t = .60 \quad W = \frac{31000 \times \overline{0.60}^2}{.0795 \times 20.6} = 6820$$

Figures 32 and 33 show respectively the load-pressure lines for these two thicknesses as parabolas and as straight lines respectively. The graphical method of constructing the parabolas by plotting

intermediate points back from a vertical line through the vertex of the parabola with the fractional abscissae $\frac{1}{16}$ P, $\frac{4}{16}$ P and $\frac{9}{16}$ P, and with ordinates $\frac{1}{4}$ W, $\frac{1}{2}$ W and $\frac{3}{4}$ W respectively is indicated on fig. 32. If preferred, intermediate points may be obtained by the use of the formula for the load-pressure parabola, assuming values of p in round numbers and computing the corresponding values of w.

The interpolation gives thicknesses as follows:

Case 1, water hammer but no truck load, t..... .57 inch

Case 2, truck load but no water hammer, t..... .53 inch

Fig. 34, the ACIPCo nomograph, is seen to give the same results but much more easily after the nomograph is once made.

For the given conditions the water hammer is more important than the truck load and the .57 inch thickness is to be selected as the net thickness. To .57 inch thickness add foundry tolerance .08 and corrosion allowance, also taken as .08 for general use, and obtain .57 + .08 + .08 or .73 for the design thickness. The corrosion allowance may of course be varied to suit the exposure to which the pipe is to be subjected both inside and outside.

Standard Thickness Classes. To avoid a very great number of thicknesses varying by small differences, Committee A-21 has adopted the suggestion of the cast iron pipe manufacturers to recommend a list of standard thickness classes varying in steps of 8 per cent, from a minimum thickness. An exact computed thickness will hence be used in the tables accompanying the specifications only when it coincides with a standard thickness; otherwise the nearest standard thickness will be listed instead. For an important job involving much pipe under definite conditions there would be no difficulty, the manufacturers state, in getting pipe of any computed thickness if desired.

Minimum Thicknesses. In the smaller sizes of pipe arbitrary minimum thicknesses, based on judgment and experience, are used for ordinary depths of cover and with considerable ranges of pressure because these minimum thicknesses are larger than the computed thicknesses. Thus in

4 in. dia., thickness of 0.40 is used for 50 to 350 lbs. incl.;
in 6 in. dia., thickness of 0.43 is used for 50 to 250 lbs. incl.;
in 8 in. dia., thickness of 0.46 is used for 50 to 200 lbs. incl.;
in 10 in. dia., thickness of 0.50 is used for 50 to 100 lbs. incl.;
in 12 in. dia., thickness of 0.54 is used for 50 to 100 lbs. incl.;

To Compute Factor of Safety. The formula for the load-pressure relationship may be used to compute factors of safety when thickness of pipe is known. As an example take the 20-inch pipe having a net thickness of .57 as above computed. For this pipe

$$P = \frac{2 \times 11000 \times .57}{20} = 627$$

$$W = \frac{31000 \times .57^2}{.0795 \times 20.57} = .6160$$

The formula of the load pressure line is: $w = \frac{W}{P}\sqrt{P - p}$ or in this case: $w \frac{6160}{\sqrt{627}}\sqrt{627 - p}$

Using the load and pressure as previously computed (see the first part of this Section) remembering to divide the load by the ratio to 3-edge bearing 1.47, and using the algebraic symbol x as the unknown factor of safety, the equation becomes:

$$\frac{1760}{1.47}x = \frac{6160}{\sqrt{627}}\sqrt{627 - 190x}; \qquad \frac{1760}{1.47}x = 246\sqrt{627 - 190x}$$

$$x = .205\sqrt{627 - 190x}; \qquad x^2 = .042(627 - 190x);$$

$$x^2 + 7.97x = 26.3$$

$$x = -3.98 + \sqrt{26.3 + (3.98)^2} = -3.98 + \sqrt{42.1}$$

$$= -3.98 + 6.50 = 2.52$$

The factor of safety for which the thickness of .57 was computed was 2.50; 2.52, obtained by short slide rule, is a sufficiently close check.

As another example in factor of safety it will be of interest to compute what the factor of safety of the same pipe would become if instead of laying it on a flat bottom trench it should be laid on blocks 6 feet apart and the backfilling not tamped, viz. the C condition of laying. For this the ratio to 3-edge bearing is .81 (see fig. 31) which is the only constant that changes in the equation.

$$\frac{1760}{.81}x = \frac{6160}{\sqrt{627}}\sqrt{627 - 190x}; \qquad x = .113\sqrt{627 - 190x}$$

$$x^2 = .0127(627 - 190x); \qquad x^2 + 2.40x = 7.96$$

$$x = -1.20 + \sqrt{7.96 + (1.2)^2}; \qquad x = +1.20 + \sqrt{9.40}$$

$$= 1.20 + 3.07 = 1.87$$

TABLE 9

Comparison of Various Barrel Thickness Standards for Cast Iron Pit Cast Pipe

All Thicknesses in Inches

DIAMETER		A.G.A.	A. W. W. A. CLASS A	MET. WATER BD. OF MASS. 50 #	CITY OF PARIS	BRITISH CLASS A	N. ENG. WATER WORKS CLASS B	AMER. PIPE MFG. CO. CLASS B	MET. WATER BD. MASS. CLASS B	A. W. W. A. CLASS B	MET. W. BD. OF MASS. CLASS C	AMER. PIPE MFG. CO. CLASS D	BRITISH CLASS B	BELGIAN FOR GEN'L WATER USE, HEAD NOT GIVEN		AUSTRIAN FOR GEN'L WATER USE, HEADS UP TO 150 # †	
Millimeters	Inches	0′	100′	115′		100′		100′	150′	200′	200′	200′	200′				
102	4	.40	.42	(.35)‡	.36	.39		.40		.45		.43	.39	.355″	.36″	.355″	.36″
152.5	6	.43	.44	(.40)	.39	.43		.43		.48		.47	.43	.394	.40	.394	.40
203	8	.45	.46	(.46)	.45	.47		.47		.51		.51	.47	.432	.44	.432	.44
254	10	.49	.50	(.51)	.48	.52		.50		.57		.56	.52	.474	.48	.474	.48
304	12	.54	.54	(.54)	.50	.55		.53	.57	.62	.61	.60	.57	.51	.52	.51	.52
355	14	—	.57	(.59)	.52	.57		.56	.61	.66	.65	.65	.61	.552	.56	.552	.56
405	16	.62	.60	(.61)	.54	.60		.60	.65	.70	.70	.69	.65	.57	.58	.57	.58
456	18	—	.64	(.66)	.58	.63		.63	—	.75	—	.74	.69	.59	.60	.59	.60
508	20	.68	.67	(.67)	.60	.65		.67	.73	.80	.79	.79	.73	.63	.64	.63	.64
604	24	.76	.76	(.74)	.64	.71		.73	.80	.89	.87	.88	.80	.67	.68	.67	.68
760	30	.85	.88	(.84)	.75	.79		.83	.92	1.03	1.00	1.01	.89				
911	36	.95	.99	.93	.82	.87	.90§	.93	1.03	1.15	1.13	1.15	.98	.89	.90	.89	.90
1,070	42	1.07	1.10	1.01	.94	.95		—	1.14	1.28	1.27	—	1.06				
1,220	48	1.26	1.26	1.15	1.06	1.03	1.10§	1.10	1.25	1.42	1.40	1.41	1.13	1.10	1.12		1.12
	54		1.35	1.23					1.35	1.55	1.53						
	60		1.39	1.35				1.32	1.50	1.67	1.70						

* Figures in left cols. are as computed from tables given in millimeters for foreign sizes 100 mm., 150 mm. etc. Figures in right columns are adjusted for 4″ (102 mm.), 6″ (152.5 mm.), etc.

† In text 14 atmos. mentioned = 205 #.

‡ Figures in brackets were computed from the Met. W. Bd. (Dexter Brackett) formula but not listed in the Met. W. Bd. schedule as thicker classes were used for the comparatively small mileage of smaller sizes.

§ Used for heads up to 100′ in New Bedford and give satisfaction. Data on use of smaller sizes of N.E.W.W. Class B not at present available.

From the pipe tables it may be found that it would take a pipe .09 inch thicker to give the 2.50 factor of safety under the C condition of loading, all else being the same.

14. Discussion of the Factor of Safety

The Committee tried various factors of safety before choosing 2.5. There is no criterion, except the obtaining of reasonable thicknesses, for choosing a factor of safety. Our predecessors, Dexter Brackett, James T. Fanning and others, obtained thicknesses not much differ-

TABLE 10

Comparison of Some A. W. W. A. and Committee A-21 Barrel Thicknesses For Pit Cast Pipe

All dimensions in inches

NOMINAL DIAMETER OF PIPE	CLASS B A. W. W. A. THICKNESS	COMMITTEE A-21 THICKNESSES 100 LBS. PRESS. & 5′ COV.			
		A	B	C	D
4	.45	.40	.40	.43	.40
6	.48	.43	.43	.50	.43
8	.51	.46	.46	.54	.46
12	.62	.54	.54	.63	.58
24	.89	.86	.80	.93	.93
36	1.15	1.22	1.05	1.22	1.13
48	1.42	1.48	1.37	1.60	1.48
60	1.67	1.75	1.62	1.89	1.75

Thicknesses *underlined* are not determined by computation but are the arbitrary minimum thicknesses chosen by considerations of strength against handling stresses. The thickness of .54 inch for 12-inch pipe for Field Conditions A and B happens to be the same both as determined by computation and as the arbitrary minimum.

ent from ours but thought they had a factor of safety of 5 with an allowance for foundry tolerance, corrosion and handling added to that. It should be said in fairness to their memory that they were aware of greater loads from extra deep trenches but did not make allowance for this unless the pipe were laid quite deep.

The Committee felt that pit cast pipe could be made somewhat thinner than the A. W. W. A. standards if laid under reasonably favorable conditions, such as flat bottom trench and backfill tamped under and along the sides of the pipe well above the middle, and they

chose a factor of safety that gave these results. At the same time it seemed a reasonable factor of safety.

In the course of these studies the table printed herein as table 9 was made by T. H. Wiggin and shows that British, Belgian and Austrian standards as well as some American standards formerly much used are thinner than A. W. W. A. standards. This fact had some weight with the Committee in its choice of factor of safety.

A study of breaks in pipe, of which Committee A-21 obtained records by questionnaire and correspondence, disclosed a few but only a few cases where breaks could be accounted for mathematically. In the majority of cases apparent factors of safety at breaking were fairly high, indicating that other causes such as incipient cracks from shocks in handling had apparently been at work.

15. Comparison of Thicknesses Obtained by the New Method with Those of A. W. W. A. Standards

The new method is akin to methods used in design of structures. A structural designer finds what the loads are and selects the proper weight of column or beam to carry it. The Committee recognized that there are limits to the refinements that can be applied in design of cast iron pipe for general use in water supply work; hence a table for the B condition of loading and a cover of 5 feet has been set up in the specifications to meet usual needs for water supply. For 50 lbs. pressure there is little difference between the thicknesses computed by the new formula for B condition and 5 ft. cover and the Class A, A. W. W. A. For 100 lbs. the new thicknesses are .05 inch to .10 inch less than Class B, 86 lbs. For 150 lbs. the new thicknesses are .08 inch to .23 inch less than Class C, 130 lbs. For 350 lbs. the new thicknesses are .19 inch to .32 inch thinner than Class H, A. W. W. A., 347 lbs.

Generally speaking, there is less increase in thickness with increase in pressure than in the A. W. W. A. standards. This is owing to the fact that the factor of safety for water pressure alone is less than for the A. W. W. A. formula and the earth load does not go up as the pressure increases.

For Field Conditions A, C and D respectively, thicknesses selected by Committee A-21 under the new method of computation are of course greater than those for Condition B on account of the more severe conditions of loading. Those who use any of these less de-

sirable methods of laying must either use heavier pipe or will have lesser factors of safety.

A limited comparison of A. W. W. A. Class B thicknesses and Committee A-21 thicknesses for these various field conditions, 100 lbs. pressure and 5 ft. cover, is given in table 10.

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ABSTRACTS OF WATER WORKS LITERATURE

Key. **30**: 402 (Mar. '38) indicates volume 30, page 402, issue dated March 1938. If the publication is paged by issues, **30**: 3: 402 (Mar. '38) indicates volume 30, number 3, page 402. Material inclosed in starred brackets, ★[ ]★, is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British).*

BACTERIOLOGY

Late-Lactose Fermenting Organisms of the Coli-Aerogenes Group. NEWELL R. ZIEGLER. Am. J. Pub. Health **29**: 257 (Mar. '39). Late-lactose fermenting organisms, which upon frequent sub-culturing, either to simple nutrient media or to media containing lactose, transform to rapidly fermenting types, have been isolated from the stools of both healthy people and those ill with diarrhea, from a blood stream infection, and from water supplies. "It seems clear . . . that such organisms are as definitely related to fecal contamination as *Esch. coli*." When found in water supplies, "it is common experience to find these organisms chiefly in supplies that almost satisfy Treasury Dept. standard, or in a highly diluted material." (As evidence of the fact that these statements are not universally accepted reference should be made to the abstract which follows.—*Ed.*) Presence of late-lactose fermenters may be explained in work of Lewis on phenomenon of dissociation in mutabile strains of *Escherichia* and *Aerobacter*, in which attention was called to fact that lactose fermentation depends on relative proportion of fermenting and non-fermenting cells present. Delay in lactose fermentation found to be independent of the total number of cells of the 2 types present in inoculum, since rapidly fermenting members of coli-aerogenes commonly present in greater numbers in polluted water supply than late-lactose fermenting organisms, late fermentation not evident in water analysis until some of volumes of water inoculated contain only one organism. Author suggests reversal of action in which *Esch. coli* and *Aer. aerogenes* form adaptive enzyme lactase from any substrate as explanation for production of late-lactose fermenting types of organisns. Conc. of nutrient material in a polluted water usually too small to permit active multiplication of cells but certain conditions may exist which may cause a decrease of lactose activity. Pathogenicity of late-lactose fermenting bacteria may be considered same as *Esch. coli* or strains of *Aerobacter*. Striking example of pathogenicity of late-lactose fermenting organism given in which organism obtained in pure culture from blood of a previously healthy adult male. In this particular case isolation of the organism from blood

stream should leave little doubt as to infectivity of the strain found.—*Martin E. Flentje.*

Slow Lactose Fermenters in Water Analysis. MacHarvey McCrady. Am. J. Pub. Health **29**: 261 (Mar. '39). Questionnaire submitted to 30 laboratory workers asking if considered advisable, in routine work, to include in coliform estimate those coliforms confirmed from lactose broth presumptives in which less than 5% or less than 10% gas has been produced after 48 hrs. incubation at 37°C. from (1) finished or unfinished waters (treated) and (2) natural waters (unfiltered and untreated). Of 25 replies 15 unqualifiedly favored inclusion, in the coliform estimate, of coliform organisms confirmed from every lactose broth tube containing gas regardless of amount. Six workers disregard small gas formers because experience has shown failure to confirm. Only 3 frankly expressed doubt of sanitary significance of slow lactose fermenters.

"The question of the sanitary significance of the presence in water of colilike organisms that produce small amounts (5 c.c. or 10 c.c.) of gas in lactose broth, upon incubation at 37°C. for 48 hours, has long been the subject of occasional informal discussion by laboratory workers; but in general these slow lactose fermenters have been accepted as genuine members of the coliform group of indicator organisms. The present *Standard Methods of Water Analysis*, for example, includes such organisms in the coliform group as therein defined. Since it is the usual practice to leave to the control authority the appraisal of the sanitary significance of the presence in a water of *any* organism of the coliform group, difficulties arising from contradictory evidence furnished, on the one hand, by the laboratory and, on the other, by the field survey of the supply, are usually (although, unfortunately, not always) readily adjusted.

"It is well known that coliform organisms frequently derive from sources unassociated with dangerous pollution, such as multiplication in sediments in mains, on wood, on other material of a vegetable nature, on tap washers, and from virgin soil that such organisms are frequently atypical in character and that many of them are slow lactose fermenters. When, therefore, the cause of and excessive coliform density is determined to be other than that of access of pollution to the supply, the coliform report is simply ignored. But is there reasonable justification for dismissing as of no sanitary significance *all* instances of slow lactose fermentation? One of the principal arguments favoring this course is that slow lactose fermentation is caused by 'attenuated' organisms which have become so 'devitalized' that they have lost their sanitary significance. This argument has been so frequently advanced that it deserves particular attention. In the first place, it perhaps will be admitted that the sanitary significance of the presence of coliform organisms in a treated, filtered, or filtered-treated water is ordinarily quite different from that of their presence in a natural water.

"Coliform organisms in a natural water serve usually as an indicator of the presence of human, animal, or soil pollution; and, depending upon the further indications furnished by the field survey of the supply, greater or less significance is attached to their presence. When a treated, filtered, or fil-

tered-treated water is examined, however, since it is usually known that the original raw water was polluted, the coliform estimate serves ordinarily, not as an index of pollution that may be more or less dangerous, but rather as a measure of the destruction or elimination, by the treatment of associated disease organisms. Here there can be no question of tolerance—if the treatment is satisfactory, practically every disease organism of the raw water will have been eliminated and, by the same token, practically every coliform organism will have been eliminated. There exists no satisfactory evidence that slow lactose fermenters are more resistant to treatment than are typhoid or dysentery organisms; nor may it be contended that a treatment which reduces the gas production of a coliform organism 95% necessarily deprives the typhoid bacillus of its pathogenicity. If, therefore, coliforms of *any* type persist in a treated water, and if their presence cannot satisfactorily be explained, the conclusion is inescapable that disease organisms may also presist in the water and that the treatment, therefore, has not been satisfactory.

"Turning now to the question of the significance of slow lactose fermenters in natural waters, it must be admitted that the experienced water bacteriologist is inclined to regard the presence of these organisms with some measure of tolerance, not because they are so attenuated that associated disease organisms may be considered to be deprived of their pathogenicity, but because they are encountered with some frequency in relatively unpolluted soil, in sediments in mains, and on plants. On the other hand, it is well known that the presence of other organisms may reduce or even prevent the production of gas by coliform organisms in the lactose broth tube. . . . Slow lactose fermenters have been shown by Parr to occur in fresh feces, sometimes in pure culture. Since he finds that they occur occasionally during periods when the normal intestinal function is impaired, the presence in water of certain slow fermenters may be of more than ordinary sanitary significance.

". . . It is evident therefore, that since the true slow lactose fermenters found in water may have derived from either fresh or stored feces, their presence, even in a natural water, cannot always be considered of no sanitary significance. Since the coliform density of a filtered, treated, or filtered-treated water is a measure of the effectiveness with which the treatment has eliminated disease organisms from the water, it is reasonable to attribute equal sanitary significance to the presence in such water of either typical or atypical coliform organisms, slow fermenters or rapid fermenters. Slow lactose fermenters are found, although in small proportion, in fresh feces, in greater proportion in stored feces, and occasionally in discharges from cases of gastrointestinal disturbance; the presence of these organisms, even in *natural* waters, therefore, cannot always be dismissed as of negligible sanitary significance. Furthermore, since other organisms contained in the sample may reduce the amount of gas produced in lactose broth by typical coliform organisms, the volume of gas produced cannot be accepted as a sure indication of the type of organism present."

Suggested that water labs. at present are well advised to include in coliform estimates, *all* coliform organisms confirmed from primary lactose broth.—*Martin E. Flentje.*

Slow Lactose Fermenters in Water Analysis. ANNA DEAN DULANEY AND E. F. SMITH. Am. J. Pub. Health **29**: 266 (Mar. '39). Attachment of sanitary significance to presence of slow lactose fermenting, coliform bacilli in water depends on proving either close relationship to accepted fecal bacteria or of their etiological rate in disease. Authors have found slow lactose fermenting and atypical coliforms often present in feces of normal and sick babies and adults. Have observed such organisms more numerous in stools from diarrhea patients than from normal individuals. Of 400 stools examined 20% contained slow lactose fermenting organisms, usually in small numbers but sometimes constituting 10 to 50% of all colonies. All investigators admit that the pathogenic properties of these atypical coliforms is very hard to prove, however, members of this group are occasionally isolated from sources where etiological rate cannot be questioned. In examination of 300 Tenn. water samples from various sources, 39 (13%) contained slow lactose fermenters, as shown by absence of gas in initial 48 hrs. but found on further examination. About 100 strains isolated, distribution included 18 members of aerogenes-cloacae group; 19 were methyl red positive and Voges-Proskauer negative strains, of which 15 cultures were indol negative, and of these 12 were citrate positive and 3 citrate negative. All but 1 produced acid and gas in cellobiose. Most of these forms are intermediates. Must be recognized that these organisms are widely present in untreated and treated waters. Organisms may or may not be detected in ordinary analyses. Non-fecal origin has not been proven and authors recommend information regarding their potential pathogenicity should be carefully accumulated and evaluated.—*Martin E. Flentje.*

Significance and Value of the Total Count in the Bacteriological Test of Water. OSCAR SPITTA. Gas-u. Wasser. **82**: 18 (Jan. 14, '39). The total count has three purposes: (1) measuring the organic pollution, (2) determination of the efficiency of natural or artificial filtration, (3) testing the effect of disinfecting agents. To measure pollution the oxygen consumed test, the B.O.D. value or the chlorine number can be used; but for very slowly flowing waters the total bacterial count is the most sensitive test for determination of local pollution or for the checking of self-purification. In testing for soil pollution it is always more important to make local sanitary surveys than to depend on a single laboratory test. Only a series of laboratory tests made on samples taken under different weather conditions can improve on local inspection. A total count is mostly without significance in water from dug wells, and for many hygienic considerations only the test for coliform organisms is of value. In artificial sand filters we get a true picture of the efficiency of the filter only when it is operated uniformly. Any interruption or forcing of its action causes an increase in the total count. The numerical result of the total count is generally not as important as are changes in its value. The limiting allowable number of 100 bacteria per ml. should not be taken rigidly but should be considered more as meaning a number with two ciphers. Many other practices in bacteriological testing are followed too much according to schedule without consideration of the scope of the test and the possibility of variation. Many times field observations are of more value. Tests for *Esch. coli* or biological examinations should often be made instead of total counts.—*Max Suter.*

Observations on the Resistance of Bacterial Spores. R. ANGERER. Arch. f. Hg. u. Bakt. (Ger.) **121**: 12 ('38). Numerous experiments were made in an attempt to ascertain why bacterial spores are so resistant to heat. Most of them were carried out with a strain of the hay bacillus type, and in many the organisms were adsorbed on to charcoal. Chloral hydrate and trichlorethylene were found capable of depriving spores of their acid-fastness, and it was thought that these de-fatted spores might be less resistant to steaming than normal spores. To a certain extent this was true, but the effect was comparatively slight. The de-fatted spores were not so heat-resistant as the normal spores, but were still far more resistant than vegetative bacilli. Spores exposed in buffer solutions of different degrees of acidity survived steaming longest when the pH was about 6.4. The presence or absence of oxygen during heating made but little difference to the rate of destruction. When adsorbed on to charcoal the spores proved much more resistant to heat than when free. The addition of agar or gelatin to the charcoal spore mixture hastened destruction of the spores, while addition of casein or peptone had the reverse effect. It is thought that these substances act by favoring or preventing the swelling of the spores.—*B. H.*

Summary of Experimental Work at Lawrence Experiment Station for the Year 1938. ANON. Massachusetts Dept. Pub. Hlth., Div. San. Eng., News Letter (Mar. '39). "Passing Merrimack River water through tanks giving thirty days' storage reduced the Coli-Aerogenes from 8,400 to 114, or 98½%, in 100 cc."

Desiccated Bile Media for Water Analysis. CHARLES F. POE. Univ. Colo. Studies **25**: 209 ('38). Best concn. of bile in medium for growing the colon group is 5-7% (3.3-4.7% dild.) at pH 7.0-7.2. Different samples of desiccated bile are sufficiently uniform to produce satisfactory growth. Aerobic, spore-forming or lactose-fermenting bacilli are inhibited in media contg. 5% or more bile. Fifty-one references.—*C. A.*

Influence of Bile and Bile Salts on Aerobacter Aerogenes. JAMES E. FULLER. Proc. Soc. Exptl. Biol. Med. **38**: 507 ('38). Thirty carefully purified strains of *Aerobacter aerogenes* were grown in suitable medium to which 1% or 5% of bile or bile salts was added, cultures being transferred each week for 5 mos. Results argue in favor of stability of cultural reactions of pure established cultures of *Aerobacter aerogenes* so far as influence of bile or bile salts alone is concerned.—*C. A.*

Specificity of Bacteriophage for Strains of the Escherichia-Aerobacter Group and for Certain Other Members of the Bacteriaceae. (*Published only in abstract.*) M. J. POWERS, MAX LEVINE AND C. S. MCCLESKEY. J. Bact. **36**: 295 (Sep. '38). Bacteriophages were isolated from sewage and packing-house waste against 11 strains of *Escherichia;* 8, *Aerobacter;* 8, *Escherichia-Aerobacter* intermediates; 2, *Proteus;* 1, *Salmonella;* 2, *Eberthella;* 1, *Alkaligenes;* 1, *Klebsiella;* 2, *Flavobacterium;* 2, *Serratia;* and 1, *Achromobacter.* Bacteriophages were purified by repeated "picking" from isolated plaques on agar. Tests for lysis were made by smearing a young bacterial culture over the sur-

face of agar, and then streaking the 'phage to be tested across the surface of this substrate. Each 'phage was tested against strains listed, also against a consid. number of additional cultures of *Esch.-A.* group and other bacteria. 'Phages isolated against strains of the genus *Esch.* showed marked tendency to lyse organisms in that genus, but not strains of the genus *A.*, and *vice versa*. 'Phages for *Esch.-A.* intermediates showed a moderate tendency to specificity for that group of cultures. Rather specific 'phages appear to exist for bacteria in each of the general *Proteus, Flavobacterium, Serratia* and *Klebsiella*. Some attacked only *Esch.-A.* strains, while others attacked both these and certain intestinal pathogens as well.—*Ralph E. Noble.*

Observations on Inactivation and Reactivation of a Bacteriophage. Studies in Bacterial Metabolism. CX. A. I. KENDALL AND CHARLOTTE A. COLWELL. J. Infect. Dis. **63**: 81 ('38). The object of this work was mainly to gain information about the chemical nature of phage by a study of the inactivation and reactivation of an *Esch. coli* phage treated with various chemical reagents. From the experiments the following facts emerged. (1) Inactivation by various aldehydes decreases with the increasing complexity of the molecule, formaldehyde being most efficient. (2) The corresponding acids, alcohols and ketones do not inactivate phage. (3) Alteration of the carbon atom adjacent to the aldehyde group diminishes but does not suppress inactivating power. It is deduced therefore that phage contains free NH_2 and NH groups and that condensation of some of these with the CHO group is responsible for inactivation. It seemed possible that reactivation might take place owing to the dissociation of the phage-aldehyde complex by dilution. Should this be correct, dilution in broth should be more effective than in water since NH_2 groups would be available in the broth to anchor any free aldehyde groups. This proved experimentally to be the case.—*B. H.*

Chromogenic Strains of Escherichia. RALPH P. TITTSLER. J. Bact. **37**: 91 (Jan. '39). Cultural characteristics of five strains of chromogenic coliform bacilli, isolated from water and human feces, were studied. On the basis of differences in fermentation of salicin and adonitol and in hemolysis, these strains fall into three distinct types. Attention is directed to the relationship of these strains to *Esch. paragruenthali* and *Esch. acidilactici*. Opinion is expressed that the five strains can conveniently be considered as chromogenic varieties of the latter, thus avoiding necessity for creating new species.—*Ralph E. Noble.*

Studies on Bacterial Nutrition. The Possible Rôle of Inorganic Salts and of Alterations in the Culture Medium in Providing Growth-promoting Effects. S. A. KOSER, R. D. FINKLE, A. DORFMAN AND F. SAUNDERS. J. Infect. Dis. **62**: 202 ('38). The object of this work was to determine whether certain organic growth-promoting substances of unknown chemical structure, usually referred to as essential foodstuffs or accessory growth factors, might not be acting by supplying inorganic salts, especially those of metals with catalytic activity, or by removal of excess of a toxic mineral, or by alteration of the physical characters of the medium. These possibilities were investigated by

adding various inorganic salts, suggested by previous beneficial reports, to a synthetic medium which alone did not support the growth of the six organisms tested, and also to the same medium with spleen extract, to observe whether growth was improved by the added salts. Results were entirely negative. Changes in the physical characters of the medium by adjustment of the oxidation-reduction potential with thioglycollic acid or cysteine hydrochloride, and by addition of agar or asbestos likewise gave negative results.—*B. H.*

Nicotinic Acid and the Fermentation of Dextrose by the Colon-Typhoid Group of Bacteria. I. J. KLIGLER AND N. GROSOWITCH. Nature **142**: 76 ('38). Experiments reported which show that although dysentery bacilli and *Bact. paratyphosum A* will grow in peptone-glucose medium, in the absence of nicotinic acid the glucose is only slightly diminished even after 48 hrs. Addition of nicotinic acid stimulates prompt and active utilization of the glucose, the acid apparently acting as a cozymase. Even with nicotinic acid *Bact. paratyphosum A* will convert glucose to acid but will produce no gas. *Bact. paratyphosum B* will ferment glucose with gas production even in the absence of nicotinic acid.—*B. H.*

The Reduction of Nitrites by Esch. coli. E. AUBEL. C. R. Acad. Sci. **207**: 348 ('38). Suspensions of washed cells of *Esch. coli*, buffered at pH values between pH 6 and pH 8, will actively reduce nitrite in presence of a hydrogen donator, e.g. glucose. This reduction of nitrite is practically completely inhibited either by presence of iodoacetate (M/600), which inhibits the dehydrogenase activity, or of cyanide (M/600), which inhibits the enzyme that activates the nitrite. Reduction of nitrite is thus dependent upon two active enzymic mechanisms.—*B. H.*

Nitrogen Metabolism of Certain Coliform Bacteria. PHILIP L. CARPENTER. J. Bact. **37**: 11 (Jan. '39). Bacteria used were typical strains of *Esch. coli*, *Aer. aerogenes* and a citrate-positive, methyl-red-positive, Voges-Proskauer-negative *Escherichia-Aerobacter* intermediate. The strains utilized ammonia when this was supplied as a sole source of nitrogen. However, when peptone nitrogen also was present, there was no apparent utilization.—*Ralph E. Noble.*

Studies of Freshwater Bacteria. V. The Distribution of Siderocapsa Treubii in Some Lakes and Streams. YVETTE HARDMAN AND ARTHUR T. HENRICI. J. Bact. **37**: 97 (Jan. '39), Bacteria presenting morphological characters of *Siderocapsa treubii* Molisch and *Siderocapsa major* Molisch were found upon glass slides submerged in various lakes and two streams. So many intermediate forms were encountered that it was considered impossible to separate these two species. *Siderocapsa treubii* was present in all alkaline, hard water lakes of the drainage type, and absent in all neutral or acid, soft water lakes of the seepage type. It was found abundantly in two rapidly flowing streams. *Siderocapsa treubii* is probably a heterotropic organism utilizing the organic radicle of organic iron compounds and depositing the iron as a waste product upon capsules of the colonies.—*Ralph E. Noble.*

Seasonal Fluctuation of Lake Bacteria in Relation to Plankton Production. A. T. HENRICI. J. Bact. **34**: 137 ('37). From paper presented to North Central Branch of Soc. Amer. Bacteriologists, May, '37. Determinations of plankton, bacteria per c.c. of water by plate counts and bacteria per sq. mm. per day deposited on glass slides, were made during a drought year in a seepage lake at weekly intervals throughout the period from melting to freezing of the lake. Lake was not appreciably polluted by material washed from surrounding land. Changes in numbers of bacteria as determined by both methods were similar to those in the total plankton, but occurred about a week later. Concluded that growth of bacteria in lake water is determined by amount of organic matter produced by the plankton.—*W. P. R.*

Relation of Bacteria to Diatoms in Sea Water. SELMAN A. WAKSMAN, J. L. STOKES AND MARGARET R. BUTLER. J. Marine Biol. Assoc. United Kingdom **22**: 359 ('37). Diatoms and bacteria are supplementary to one another in the life cycle in the sea. Diatoms synthesize org. matter from simple chem. substances produced in the decompn. or mineralization of org. matter in the sea by bacteria. Dead diatoms in sea water are rapidly decompd. by bacteria, accompanied by marked increase in bacterial population. Bacterial nos. reach peak in short time and then drop to low and fairly const. levels. Living diatoms are not attacked by bacteria of sea water. In breakdown of copepod plankton, distinct parallelism was found between O consumption, bacterial multiplication and NH_3 liberation, but in diatom plankton no such parallelism exists. N was liberated very slowly and bacteria increased only to limited extent probably because of feeding of bacteria on substances excreted by diatoms or upon dying diatoms. Consumption of O was due to respiration of diatoms themselves. Living diatoms, even when photosynthesis is excluded, are resistant to bacterial attack but are gradually consumed by animal members of the plankton.—*C. A.*

MICROBIOLOGY

Protozoan Plankton as Indicators of Pollution in a Flowing Stream. JAMES B. LACKEY. U. S. Pub. Hlth. Repts. **53**: 2037 (Nov. 18, '38). The lack of accurate and specific knowledge concerning the ecology of stream protozoa and their various reactions to pollution is believed to be a result of an approach which has been too broad. This paper represents an attempt to remedy this situation by studying the reaction of small groups or species to pollution. With the development of information of this type the careful biological examination of a sample for species or group of species of known reaction to pollution can become a more simple routine and more easily performed than the 5 day B. O. D. test or the coli-aerogenes count and will constitute a valuable supplement to these established tests. The study described, was made in '37 on the Scioto River in Ohio which has both grossly polluted and relatively clean reaches for comparison. Over 200 samples from 16 stations were examined, some fresh others formalin preserved. One hundred ml. of the sample was concentrated by centrifuging and the protozoa counted in drops of this concentrate. This method permitted a high magnification (537 diameters) which increased the accuracy of identification and facilitated counting. The

relative abundance of 182 species of protozoa was noted. The flagellate protozoa favoring pollution were *Eudorina, Pandorina, Spondylomorum, Gonium,* and the species of *Euglena* and *Trachelomonas* which occurred in the Scioto. Ciliate protozoa abundant in the polluted sections and decreasing downstream were: *Amphisia, Aspidisca, Charchesium, Chaenia, Chilodonella, Cinetochilum, Colpidium, Colpoda, Epistylis, Euplotes, Glaucoma, Lacrymaria, Lembus, Lionotus, Loxodes, Opercularia, Oxytricha, Paramecium, Plagiopyla, Pleurotricha, Stentor, Stylonichia* and *Vorticella.* Those dropping in number in the polluted section and increasing downstream in cleaner water were: *Askenasia, Actinobolus, Bursaria, Codonella, Coleps, Cyclidium, Didinium, Frontonia, Halteria, Holosticha, Holophrya, Loxocephalus, Nassula, Onychodromus, Prorodon, Strombidium, Strobilidium, Urotricha* and *Uronema.* Two new and especially good indicators which reacted negatively to pollution were *Cryptomonas* and *Chrysococcus.* Conclusions were that specific identification should be made, that fresh samples facilitate identification, that it is unsafe to draw conclusions on occurrence alone (nos. present at polluted and less polluted zones must be considered) and that the biological method is a feasible and practical means of determining the extent of pollution.—*Theodore A. Olson.*

The Manipulation and Counting of River Plankton and Changes in Some Organisms due to Formalin Preservation. JAMES B. LACKEY. U. S. Pub. Hlth. Repts. **53**: 2080 (Nov. 25, '38). The identification and enumeration of certain plankton forms has always been difficult because of changes which take place in the preserved sample or the difficulty of counting living moving organisms in a fresh sample. In this study an attempt is made to reduce some of these difficulties. About 100 fresh and 166 formalin preserved samples collected on alternate weeks respectively from the Scioto River of Ohio in '37 and examined by the author, provided information on the effects of formalin preservation. A table listing 234 species of protozoa and the effect of 4–5% formalin upon the form, size, color, pellicle and other diagnostic features of each is included in the paper. The study indicated that a familiarity with living organisms and the changes brought about by preservation will allow accurate identification even in preserved samples and that under certain conditions preservation might actually be an aid in making counts. A 4 or 5% solution of formalin is recommended. Samples from the Scioto and from an activated sludge plant were used to check a new counting method. The volume of the plankton catch obtained by centrifuging and decanting 100–200 ml. of sample was so adjusted that 1 drop = 1 or 2 ml. of original sample. Ten to twenty drops of this concentrate were examined by placing a 25 mm. cover slip over a small drop and counting two strips at right angles to one another through the middle of each drop. By this method both low and high power objectives could be used interchangeably,—a feature of considerable value in counting and identification. Checks on larger organisms indicated differences too small to be significant in using strips as contrasted to counting whole drops. Examination of the worm *Aelosoma* in drops of activated sludge indicated that each drop was a fair sample.—*Theodore A. Olson.*

Biological Investigations on Sewage in a Stretch of the Elbe Below Hamburg (Ger.). A. MESCHKAT. Arch. Hydrobiol. **31**: 399 ('37). Wass. u. Abwass. **35**: 284 ('37). Examination of the littoral fauna of a stretch of the Elbe near Blankenese showed considerable increase during recent years in pollution of the banks by sewage of Hamburg. Slimy coatings of *Vorticella*, sewage fungus, and bacteria were present but all other animals were out-numbered by tubificids of which 4,936 were counted per 100 sq. cm. Conditions were favorable for the development of these worms and only at certain seasons when numerous birds were present or when there was continued frost were their numbers greatly reduced. These worms have increased to more than three times the number found 15–20 yrs. ago. Chironomid larvae were absent and few snails were found. There was no evidence of any effect of waste waters from the oil industry.—*W. P. R.*

Algae as Indicators of Water Conditions. MARIE ROSENBERG. Off. Cir. Br. W. W. Assn. **21**: 163 (Feb.–Mar. '39). *Pub. Health Services Congress, meeting under auspices The British Waterworks Assoc. Nov. 17, '38.* Plants represent first stage of life cycle in any water body, animals develop later. Term "algae" covers vast number of species with worldwide distribution and comprises habitats of very different nature. Factors necessary to growth are light, temp. and dissolved substances in water. Found a close relation exists between amount of light available for an algal cell and rate of divisions, the more light the more divisions. Except in few cases, increase in temp. increases number of cells produced per time unit. Dissolved substances chiefly organic and inorganic substances derived from rocks, soil and lake bottom; main ones are: $-NO_3$, P_2O_5, $CaCO_2$, SiO_2. Research progressed far enough to now foretell in many cases likely algal flora if main characteristics of water known. Geologic, climatic, and human influences largely responsible for changes in conc. of chemicals in natural water. Entrance of sewage may speed up evolution of lake.—*Martin E. Flentje.*

Freshwater Biological Assoc. of the British Empire. Sixth Annual Report. (Yr. ending Mar. 31, '38). Part I. Director's report with description of lab. facilities, personnel changes, etc. Part II. Articles on Research. *Bathymetric Surveys and Lake Deposits.* C. H. MORTIMER AND E. B. WORTHINGTON. An echo-sounding device emitting a supersonic sound impulse at frequent intervals and recording the time taken for echo to return to surface on a continuous chart was used to obtain accurate depth record of Windermere lake. 300 cross sections obtained in few weeks. Found that instrument also gave information of depth of soft mud deposits overlying hard lake floor. Opened up interesting field for further research. *The Chemical Budget of a Lake.* C. H. MORTIMER. Lake plants, either rooted vegetation along the shore or microscopic algae in the water, build up complex organic compds. which are the ultimate food source for animals, from simple inorganic chemical substances in manner similar to land plants. Nitrogen and phosphorus supply may limit growth. Daily record of two streams flowing into Windermere lake show nitrate content is higher in winter than summer; during this period much of nitrate not used by land plants but is washed out of soil by

rain, in summer lower conc. may be due to increased nitrate demand of land plants on watershed. Windermere with av. outflow of 1.4 mil. cu. m. daily, has excess of 143 metric tons of nitrate in outflow water above amount brought in by main inflow streams. With av. retention period of 9 mo., heavy rainfall in first 3 mo. of yr. is followed by heavy diatom crop in Winderemere, with light rainfall crop is small. *The Culture of Algae and its Applications.* M. ROSENBERG. In a 3 yrs. study much information obtained regarding requirements for growth of algae. Physiological requirements of algae belonging to different groups differ widely. *Staurastrum* and *Closterium*, both characteristic of primitive waters, flourished best at low conc. of nutritive chemicals; *Dinobryon* and *Asterionella* grew abundantly at high conc. and not at all in more dilute solns. Volvocales, Protococcales and Ulotrichales show high division rates in relatively conc. solns. in lab., while Desmids will divide best in very low conc., 50 p.p.m. total conc. being good av. for number of species. Diatoms, especially *Asterionella* and *Tabellaria*, show their optimum division rate with low light intensities, in media with a high ratio of nitrogen to phosphorus. *Oscillatoria* shows good growth in solns. of low conc. at low light intensities. Example given of influence of algae on trout caught in Loch Levan (Scotland) in '37, marked decline in number of fish caught during time of max. development of bluegreen alga *Oscillatoria Borneti* which colored water brown; with disappearance normal amount of fish again caught. *Progress of the Salmon Investigation.* K. R. ALLEN. Investigations have been carried on for 3 yrs. to find out about habits and growth of salmon under conditions prevailing in river Eden. Well-marked seasonal changes found to occur, closely related to water temp., salmon grows most rapidly in June, growth gradually falls off and ceases in Oct., from then until Apr. no growth takes place, in Apr. recommences comparatively suddenly. Grow best between 10° and 14°C. (50°–57°F.).—*Martin E. Flentje.*

The Nitrogen Balance of Large Bodies of Water. C. H. MORTIMER. Off. Cir. Br. W. W. Assn. **21**: 154 (Feb.–Mar. '39). *Pub. Health Services Congress, meeting under auspices The British Waterworks Assoc. Nov. 17, '38.* In large water bodies, algae rely on nitrate dissolved in water for nitrogen supply. Nitrates produced by nitrification in soil; if not used up by plants nitrates are washed out and form large part of nitrate supply of lakes, this procedure happening largely in winter. Another source is decomposition and mineralization process in water and mud of lake itself. Has been found that physical-chemical conditions existing in lakes can be conveniently described in terms of oxidation-reduction potential, Eh_5 .350 (Eh at pH 5) volts is critical potential for major oxidizing and reducing reactions in natural waters, apparently only above this potential can nitrification occur; this remaining true for lakes, either deeper or less productive, in which the O in the lower water is not completely depleted. Attempt made to calculate nitrogen budget for Windermere Lake. This lake, dammed by glacial action, is divided into 2 basins; larger one 3.4 sq. mi. in area and with 219′ max. depth, smaller basin 6 mi. long, 2.5 sq. mi. in area and 132′ max. depth; total cap. of lake 346 mil. cu. meters and av. outflow 1.4 mil. cu. meters daily, "storage" being approx. 9 mo. From chemical analyses and flow records annual excess of in-

flow over outflow of 20–50 metric tons of nitrogen exists. Study now being made to detn. what becomes of nitrogen, if due to nitrogen loss or storage in mud. Study deemed important from standpoint of waterworks and fisheries. ★[See also previous report by same author in preceding abstract. The more comprehensive study reported in this later article included an allowance for nitrogen introduced by sewage from a village of 6,000 pop. on the watershed. This addition accounts for the apparent inconsistency in the nitrogen balance between the two reports.]★—*Martin E. Flentje.*

The Availability of Different Forms of Nitrogen to a Green Alga. C. A. Ludwig. Am. J. Botany **25**: 448 ('38). *Chlorella* (Wann's No. 11) was grown under artificial light in sterile cultures to which different kinds and amounts of N were added. N absorbed by plant was used as measure of its availability. N of KNO_3 was utilized. N of org. and inorg. NH_4 salts was generally more available than N of KNO_3. N of NH_4 formate was as available as N of KNO_3, that of NH_4OAc was less so and that of NH_4 propionate could not be used. Ca, Mg or Al did not increase availability of N in fat acid salts. Acetamide, urea, guandine carbonate, uric acid, several amino acids, peptone and dil. solns. of KNO_2 are suitable as N sources. $CaCO_3$ was beneficial in some cases, probably by effect on pH of medium. Results confirm idea that green plants need not depend on nitrification to make org. N available, but can utilize such N as soon as ammonification has occurred, or sooner. 102 references.—*C. A.*

Objectionable Algae and Their Control in Lakes and Reservoirs. G. W. Prescott. *Reprint by* Bur. of Gov. Res., Louisiana State Univ., *from* Louisiana Munic. Rev. **1**: Nos. 2 & 3 (Jul.–Aug., Sep.–Oct., '38). Algae may be troublesome to water supplies by giving off foul odors and disagreeable tastes when either dead or alive, through suffocation of fish and animal when oxygen supply is used up, and in some cases, when superabundant, through killing of cattle and fish. Algae are the chlorophyll-bearing plants of aquatic habits (red, brown, green and blue pigments may be present) which do not reproduce by seeds and which have no roots, stems, or leaves. Fresh water algae belong largely to 2 groups,—the blue-green algae (Myxophyceae) and the grass-green (Chlorophyceae). In addition classes of swimming plants cause trouble, *Synura* being one. Blue-greens by far most troublesome; thrive in warm water 25°–30°C, in water having high CO_2 content, and require large amt. nitrogenous material. Can develop very rapidly. The floating blue-greens having characteristics of floating high in water and stickiness of sheath are worst pests. Excessive growths may clog filters, produce tastes and odors, cause troublesome colloidal turbidity when "bloom" breaks up, and may, by using up oxygen, convert reservoir or lake into veritable aquatic graveyard. Copper sulfate and chlorine used for control, first most common. Dosage dependent on type present, temp., suspended matter which absorbs chemical, behavior of particular algae, and alkalinity—higher alk. water requiring more copper. Exptl. control methods for each lake should be used and most effective adopted.—*Martin E. Flentje.*

Animal Life in Fresh Water. A Guide to British Fresh-Water Invertebrates. H. Mellanby, Methuen & Co., Ltd., London, '38. 304 pp. A guide book, intended primarily for use in schools, for the indentification of invertebrate animals found in fresh water. Includes chapters on fresh-water sponges, hydroids, flatworms, true worms, crustacea, insects, arachnids, molluscs, polyzoa, rotifers and protozoa. In small groups species are described, but in larger groups, e.g. insects, methods for identifying families or genera only are included.—*W. P. R.*

WATER SUPPLY—GENERAL

Delaware Water for New Jersey. ANON. Eng. News-Rec. **122**: 432 (Mar. 30, '39). Brief details given regarding plan for new water supply from Delaware R. for metropolitan district of N. J. recommended to state legislature by committee appointed by Governor. River water would flow through 49-mi. aqueduct constructed in abandoned Delaware and Raritan Canal to Bound Brook, where it would be pumped into 600-mil. gal. storage reservoir and, after filtration, would flow through 21-mi. 200-m.g.d. transmission main tied into Wanaque system now serving large part of northern N. J. State owns canal right-of-way and by acquisition of canal property is said to possess water rights originally conferred on canal company, which permit diversion from Delaware R. without further consent of Penna. Twin, rectangular concrete conduits are recommended for aqueduct. Ten 20-m.g.d. pumps would be required to pump into proposed reservoir formed by construction of concrete gravity dam at Dock Watch Hollow. As it may be desirable in future to raise dam height to increase storage, pressure filters would be more desirable than those of gravity type. Filters 30′ in length and 9′ diam. proposed, each with capac. of about 1 m.g.d.: 200 such units required. Transmission main would consist of two 6′ diam. pipes, and 9′ tunnel 3500′ in length, through Watchung Mountains. Capital cost estimated at about $33,700,000 and annual operating cost at about $1,125,000.—*R. E. Thompson.*

More Water for Utah's Cities and Farms. E. A. JACOB AND E. O. LARSON. Civ. Eng. **9**: 27 (Jan. '39). Projects now under way for development of water resources in Utah include: (1) an earth dam 155′ high and 1,700′ long at Deer Creek, near Provo, (2) the Weber-Provo Diversion Canal enlargement to divert 1,000 c.f.s. to the Provo River, (3) the 5.5-mi. Duchense Tunnel to divert waters from the Colorado watershed to the Provo R., (4) enlargement of the Provo Reservoir Canal to capac. of 550 c.f.s., and (5) the Salt Lake City Aqueduct, 42 mi. long, to cost $13,100,000. Development of storage on the Provo R. has been investigated and the construction of a storage dam at the Deer Creek site has been agreed upon. Water for this reservoir will come from four sources: Duchense R., Weber R., Provo R., and the return seepage flow from the use of project waters for irrigation. The reservoir will be constructed with a live storage capac. of 147,000 acre-ft. Inclusion of the Salt Lake City Aqueduct is of importance to that city as the suburban areas can be irrigated by waters from the aqueduct until such time as the water is otherwise needed in the city. Deer Creek earth dam now under construction.—*H. E. Babbitt.*

Waterworks Efficiency at Ottumwa. W. W. DeBerard. Eng. News-Rec. **122**: 20 (Jan. 5, '39). Data regarding operation of waterworks of Ottumwa, Iowa, acquired by city in '10. Hydro development, 1 mi. upstream, provides all power for operation except during extreme low water and floods, and excess is sold to local power company. Operating profit of dept. (water and hydro) in '38 exceeded $135,000. Outstanding bonds ($108,000) will be retired within 2 yrs., entirely from earnings, no taxes having been levied since '26. Step-rate schedule starts at 25¢ per 1000 gals. up to 30,000 gals. per mo., with 10% discount for prompt (10 days) payment. For 6 mil. gals. or over per mo., rate is 6½¢. Population is 35,000 and per capita consumption 85 gals. per day. Av. amounts of chemicals used in purification and softening process are: iron sulfate, 2–3 g.p.g.; lime, 9–10 g.p.g.; soda ash, 6 g.p.g.; chlorine, 6.1 lbs. per mil. gal; ammonia, 3.4 lbs. per mil. gal.; activated carbon, 0.16 g.p.g. Chemical cost is about $25 per mil. gal. Total hardness reduced from 20–25 to 5 g.p.g. Carbonation is effected with carbon dioxide generated by an oil burner, 0.02 gal. of oil per 1000 gal. of water being used. Application of carbon dioxide is automatically controlled by a Micromax regulator to maintain pH at 8.2–8.3, which has been found to be optimum point for prevention of corrosion and lime deposits. Meters are read quarterly, with exception of large industrial and commercial installations, which are read monthly. Readings are recorded directly on postcard bill, which, after passing through office routine, is mailed to customer. Delinquencies amount to only $200–$300 per yr. No regular schedule of meter removal is necessary.—*R. E. Thompson.*

Hurricane Damage and Repairs to Bristol, R. I., Water Works. Anon. Am. City **53**: 12: 64 (Dec. '38). One of the important elements in the Bristol water system is the Kickemuit Reservoir located so close to tidal water that there are tide gates in the reservoir spillway. The Sept. hurricane and attendant tidal waves filled this reservoir with salt water and flooded the pumps —both electric and steam—at the water plant. Conditions required a house-to-house system of purveying water to inhabitants of Bristol, Warren and Barrington. The steam pumping equipment was gotten ready for operation, pipe line breaks were repaired, and a 900′ temporary line to connect with the Shad Factory reservoir was installed. One week after the storm, potable water was pumped into the mains again. The Bristol system is one of those owned by the Amer. W. W. and Electric Co.—*Arthur P. Miller.*

Flood Protection at Louisville. L. S. Vance. W. W. Eng. **91**: 1644 (Dec. 21, '38). After Louisville, Ky., pump station bldgs., which originally had been designed to be 7′ above 1884 stage of 46.7′, were flooded by 57.1′ flood of '37, plans were proposed for protection in future. Plan adopted provides for 60 m.g.d. pumping capac. (2–30 m.g.d. units) in vertical shaft electric pumps with motors approx 10′ above '37 water stage, and for protection of steam plant to a river stage of 55. Steel bulkheads installed, window sills raised 5′, new discharge pipe lines built and 3 separate electric supply lines provided. Other precautions included wooden poles for 2 power circuits, power line and telephone line laid underground.—*Martin E. Flentje.*

Brantford, Ont., Annual Report, 1938. F. P. ADAMS. W. W. Inf. Exch., Canadian Sect. A. W. W. A. **3**:E:1:1 (Mar. '39). Statistics given from report include: cost of chemicals, $2.67 per mil. gal.; max. and av. daily pumpage, 3.64 and 2.542 m.g.d., respectively; av. daily per capita consumption, 80.5 gal.; population, 31,549; wash water used, 1.27% of water filtered.—*R. E. Thompson.*

Water Supply Progress—A Review. REEVES NEWSOM. W. W. and Sew. **86**: 1 (Jan. '39). A general paper recounting developments and trends in water supply and water treatment practices during '38.—*H. E. Hudson, Jr.*

The Water Supply of Buenos Aires. J. BACIGALUPPI. Bol. Obras Sanitarias Nacion (Buenos Aires) **1**: 132 ('37). Account of the development and illustrated description of present works. Water drawn from the estuary of the La Plata R. through a tunnel below the river bed to the Palermo works. Aluminoferric (40–155 p.p.m.) added in the suction chamber of the pumps, which raise the water to a level from which it flows through the treatment plant. Sedimentation reduces the turbidity from 70–800 p.p.m. to 10–20 p.p.m., removes almost all color and greatly reduces the bacterial count. Copper sulfate (2 mg. per liter) is added in the sedimentation tanks when necessary to control algal growths. After sedimentation the water is treated with lime 5.65—27.11 mg. per liter) to reduce the concentration of agressive carbon dioxide and raise the pH value, and with chlorine (0.15–0.20 p.p.m.) to reduce the bacterial load on the filters. Both slow and rapid sand filters are used. Slow filters have superficial area of 26,400 sq. m. and are 1.6 m. deep; they treat 6.72% of the supply. Rapid filters have area of 12,300 sq. m., are 0.6 m. deep, and treat remainder of the supply. Chlorine (0.1–0.3 mg. per liter) is added in the filtered water tanks. Pumping plants and distribution system are described. Pop. served is 2.3 mil. Plans for extension of the supply are described. These include new intake, additions to settling tanks, conversion of slow to rapid filters, and equipment for ammonia-chlorine treatment at different stages and for use of carbon to remove odors.—*W. P. R.*

Further, from same article: Extensions planned for population of 6 million with av. demand of 500 liters per cap. per day. Present water works includes sulfuric acid and coagulant manufacturing plants. Coagulant pumped to Palermo Treatment Plant through double line of wood pipe 15,000 meters long.—*J. M. Sanchis.*

Water Supply for the City of San Francisco (Argentina) and Intermediate Communities. RAUL A. CALANDRA. Bol. Obras Sanitarias Nacion (Buenos Aires) **2**: 473 (Nov. '38). Detailed presentation of a mathematical analysis made to determine the most desirable of four projects under consideration for furnishing water to the City of San Francisco (pop. 30,000) and eight smaller communities located along the line of the aqueduct. The projects considered were as follows: A_1—A low pressure gravity flow aqueduct of adequate capacity to supply three times the present pop. This project, which involved pumping into distribution systems, made possible use of low pressure pipe thus saving first cost. A_2—The same type of aqueduct as in A_1 but to consist

of two conduits each adequate for 1.5 times the present pop. One of these to be built at once and the other, 18 years from now so as to be ready at beginning of the twentieth year, when the capacity of the first one is expected to become inadequate. B_1—A single conduit high pressure gravity flow aqueduct of sufficient capacity for three times the present population. Pumping not necessary, but a stronger and more expensive type of conduit required. B_2—A double line aqueduct designed for the same conditions as A_2, but for gravity flow under sufficient pressure to eliminate pumping. Results of the study indicated that project A_2 had the following advantages over the others: (a) Lower initial investment (73.1% of the cost of A_1). (b) Possibility of designing the second pipe line more adequately for future needs after observing the actual trend of pop. increase during the 18 years during which the first line will serve. (c) Greater security of supply with double aqueduct. (d) More equitable distribution of interest and amortization costs due to extension of the amortization period from 36 to 54 yrs.—*J. M. Sanchis.*

Urban Water Distribution Systems of the Argentine Republic. EVARISTO ARTAZA. L'Eau (Fr.) **31**: 114 (Oct. '38). Water consumption in many places in Argentine reaches high figure because of location of communities and liberality with which water is supplied. Table given lists 77 cities and districts with water supplies in '36 serving total pop. of 4,759,200. Daily per capita consumption ranged from 47 to 477 liters. In large cities average is 400 liters, in smaller cities, 200 liters, and in small communities, 100 liters. Consumption is small in unsewered districts, and author estimates that with sewers, consumption would be doubled. In summer consumption in Buenos Aires reaches 500 liters per capita per day. In Buenos Aires 12% of water is used in public service, 6% in industry, 70% in domestic services, and 12% lost in distribution system and in dwellings. Public uses of water include streets and parks, public buildings and institutions, shipping, fire service, water and sewage plants, and flushing of water mains and sewers. Industrial water consumption is relatively low due to use by industries of abundant well water of good quality found at depth of 40 meters. Of 287 liters per capita per day for household use, estimated 1.5 liters are used for drinking, 4.5 for food preparation, 50 for laundry, 30 for lavatories, 30 for baths, 80 for toilets, 41 for hot water, heating, etc., and 50 for dish-washing and house-cleaning.—*Selma Gottlieb.*

South American Water Works, Past and Present. ARTHUR T. COOK. W. W. Eng. **93**: 126 (Feb. 1, '39). While S. Amer. known as land of little sanitation it surprisingly was American birthplace of both sanitation and water supply. In recent yrs. considerable improvement made. Aqueducts and drainage ditches (called "asequias") first used for transmission of water. Later, water supplied by water peddlers, called "aquadors." Supplies in Chile inadequate in many cases and not safe, problem now being attacked by government. Water supply work in Uruguay and the Argentine of superior quality; at present greatest sanitation activity exists in Colombia and Venezuela where program costing $100,000,000 is just getting under way. S. Amer. has great variations of rainfall; on north coast during wet months rainfall

may vary from 5 to 20″ per mo. Chlorination now accepted without question, formerly objected to. Difficult to set proper water rates and make collections. Advice given to engineers contemplating going to S. Amer.—*Martin E. Flentje.*

London's Water. Safeguards Against Pollution; Results of Chemical and Bacteriological Examination. *Extracts from 32nd. Annual Report of the Metropolitan Water Board for 1937.* ANON. Surveyer (Br.) **95**: 311 (Feb. 24, '39). *Bacteriological Section:* Comparison is made of primary enrichment media which shows that few presumptive failures are encountered when reliance is placed on lactose McConkey broth. Studies of the indole presumptive test proved that many of the positive tubes did not contain coliform organisms. The citrate test has been introduced into the routine classification of coliform types. The tellurite methods for isolation of streptococcic forms continue to give promising results. *Biological Section:* Investigations into the algal flora of raw and stored waters. The results obtained from studies of the Queen Mary Reservoir show that a standing reservoir is characterized by a fall in concentration of nitrate nitrogen which leads to development of blue-green algae, like *Oscillatoria.* Studies being extended to primary filtration in attempt to explain cause of increase in size of sand grains. *Chemical Section:* Account given of use of new photo-electric turbidimeter. Use of zinc for water pipes and for tracing leakage is discussed and tables included showing degree of aeration of raw waters and deep well waters. *Works Efficiency:* Purification, chlorination, filtration rates, and bacteriological efficiencies. Under other sections subjects treated include discussion of the increased frequency of sampling of well waters to avoid a repetition of the Croyden epidemic; periodic examination of raw waters with tabulated data on results obtained; summary of consumer complaints; possibilities of use of the Thames as a source of water; and a concise account of use of fluorescein and other studies of underground water flow in the Lee Valley. Rainfall data on the watershed of the Thames are reported in detail. Analyses of the water supply from the Thames watershed above Teddington are tabulated for 5 yrs. preceding '38 with improvement in quality shown under every head. Advance in purity figures for waters not chloraminated terminally is greater than in preceding year, but such is to be expected, since, as all filtered waters are now terminally treated, this consists entirely of well water. Pointed out that measurable pollution of Queen Mary Res. may result from sea gulls, as one gull may contribute 50 to 100 million *Esch. coli* daily. Examination of the primary sand filters at Kempton Park shows sand to be rounded and dark in color. Treatment with acid readily removes the outer coat revealing the original, bright, crystalline sand grains. Explanations of cause of this coating are discussed and it is concluded that condition can be remedied by putting the sand through secondary washers. In the control of wells treatment was so arranged that water could be sampled before and after treatment making possible dosing adjustments which are checked bacteriologically. Officially recorded complaints totaled 199, of which 16 taste complaints were justified and 27 were justified under the heading "worms, shrimps, insects, etc."—*H. E. Babbitt.*

Water Supply in 1938 (in England). ANON. Surveyor (Br.) **95**: vi (Jan. 27, '39). The intense activity and marked acceleration in construction of water supply schemes which has been noticeable during past few years has continued, and during the last year a number of schemes involving large capital expenditure have been completed. Prevention of pollution has received attention, spurred by the Croyden epidemic in late '37. Chemical treatment of all water from wells of the Metropolitan (London) Water Board has been considered. Lack of a recognized standard of purity has been felt. There is lack of legal recourse in the event of ground water pollution which is not felt with respect to surface water pollution. In protecting the purity of water supplies the dangers of pollution in service reservoirs are being guarded against by covering such structures. The Ministry of Health has leaned towards a policy of suspecting the purity of all ground water supplies, requiring chlorination as a necessary precaution. Increased pollution of London's ground water supply has been a cause of growing alarm. Throughout the country there is sufficient ground water to supply all needs but, unfortunately, it is unevenly distributed and what there is requires protection from pollution. The Central Advisory Water Committee was formed to advise government departments on questions relating to the conservation and allocation of water resources and on any proposed amendment to the enactments relating to water. The Underground Water Subcommittee was of opinion that the present lack of control has often led to competitive boring and waste of water. The Planning Subcommittee recommended the work of assessing water supplies so that proposals could be formulated for the full use of existing resources. Various changes in the organization of subcommittees and the creation of regional authorities have been made. A set of regulations for the grounding of electrical circuits on water mains has been adopted during the year. Some interesting research problems have been investigated, including experiments on stream bed scour which have been made at the Imperial College of Science and Technology. Bellmouth, overflow, and other types of spillways have been investigated, particularly in connection with the Jubilee Reservoir at Hong Kong. A new method for calculation of shearing stresses in gravity dams has been proposed by Serge Liliavasky. Investigation has been made of the effect of frost on water pipes leading towards a method to care for this hazard. Air-raid precautions for water works have been discussed in the literature and have been put into effect in the field with the assistance of a government grant of 50% for this work. Some of the principal works completed during the year include: Liverpool's third pipe line from Lake Vyrnwry; a new 210 mil. gal. (Imp.) reservoir at Durleigh; and a 360 mil. gal. reservoir for the Water District of the County of Renfrew.—*H. E. Babbitt.*

Water Supply and Sanitary Engineering in 1938 (England and France). ANON. The Eng'r. (Br.) **167**: 67 (Jan. 13, '39). Article devotes much space to sewerage projects as well as major and minor water works schemes in England and major schemes abroad. Among major water schemes in England are the Ladybower Reservoir for the Derwent Valley Water Board, and the Vyrnwry Aqueduct extensions for Liverpool. In France several towns have completed plans for large-scale work which it is hoped to put through now that the outlook has greatly improved. An interesting program is the grouping of

communes on the valley of the Var for distribution of water over large areas. Ozone plants have been completed at Marseilles, Rouen, and Roubaix-Tourcoing, while at Saint Maur filtering station near Paris the experimental ozone plant has been replaced by one dealing with 151,000 cu. meters of water per day. Financial difficulties have delayed many major schemes in other districts in France, which have been restricted also by considerations of danger from air attack. At Rangoon, in Burma, work has proceeded actively on the construction of the 14,800 mil. gal. (Imp.) reservoir at Pegu Yomas.—*H. E. Babbitt.*

River Control and Water Storage in 1938. ANON. The Eng'r. (Br.) **167:** 29 (Jan. 6, '39). Only two works of magnitude were in course of construction in England during the year. Both concerned with water supply. The Haweswater Dam, which will create a reservoir in the Mardale Valley, from which water will be drawn for Manchester, and the Ladybower Reservoir now under construction for the Derwent Valley Water Board. Considerable work under way in other countries. In France the Genissiat scheme is probably the largest of its kind to be built and has points of similarity with Boulder Dam in America. The new dam and bridge research laboratory at the Office Nationale des Recherches et Inventions at Bellevue, near Paris, marks an interesting advance. In Egypt the remodelling of the dam at Assuit to aid in control of the Nile is a work of great magnitude. An interesting piece of work, although not of great magnitude, has been the construction of a dam at Victoria Falls on the Zambesi River in South Africa. Among the principal dams under construction in America may be included the Parker Dam on the Colorado River, the Pickwick Landing Dam and other works of the T. V. A., and the Grand Coulee Dam on the Columbia River.—*H. E. Babbitt.*

Netherlands Waterworks Association. Official Report of the 64th Convention at Maastricht, Sept. 22, '38. Water (Netherlands) **23:** 20 (Jan. 27, '39). *Address of the President,* J. VAN POELGEEST. Refers to the successful development of the South Limburg Waterworks, under J. J. H. Vos, since its start in '27. Of the 54 communities (gemeenten) in South Limburg the company now serves 45, delivering annually 1,750,000 cu. meters of water through 17,500 connections. He announced the nomination of two new committees, on lead pipe and on the examinations for the water fitter's diploma. He reported his attendance on Aug. 14 at the 40th anniversary of the opening of the Tilburg waterworks. Forty years ago, there existed in Holland about 50 waterworks, supplying about 60 communities. The Dune supply of Amsterdam was the first to be established in Holland, in 1853. By 1898, 45 years later, all the larger centers had their own supplies. The succeeding 10 years saw about 30 new works started in the centers of moderate size. Now, 30 years later, there are 215 waterworks supplying water in upwards of 700 communities out of the 1050 in Holland. This last has been the era of development of inter-community or district supplies, of which that for the south of Limburg constitutes an outstanding example. Communities still lacking supplies are, some of them, rather isolated, but for the most part they are aggregated into groups in a (comparatively) few districts with plans for supplying them already in shape, economical rather than technical reasons imposing delay. It is hoped that

another 15 years will see every community in Holland with a piped supply. *Subjects discussed during the convention*: Remote pressure control at Schimmert. Experiences with the divining rod. Water works advertising. Dynamiting of wells to increase yields. Pressure boosting for fire extinguishing. Lead joints and pressure limitations. Preferability of lead wool for joints. Rubber joints. Joints in bad ground. Pressure fluctuation in mains. Children's allowances deducted from water bills.—*Frank Hannan.*

Netherlands Government Water Supply Bureau Annual Report for '37. ANON. Water (Netherlands) **23**: 18 (Jan. 27, '39). *A Review.* Report refers to the important booklet commemorating the Bureau's 25th year and mentioning leading events of '37. With the rapid extension of piped water supplies throughout Holland, a series of new problems has arisen. Increasing population density is adding in different ways to the difficulties of securing suitable drinking water and government intervention may have to be invoked. Military considerations also involved. The government is being increasingly held responsible for the purity of water supplies, the Croydon, England, typhoid epidemic being looked upon as a standing warning. Demands for piped supplies now being voiced from the more remote, and therefore less remunerative, areas may help out the unemployment problem. Water supply in each of the 11 provinces is separately reviewed and various others of the Bureau's numerous activities are briefly chronicled.—*Frank Hannan.*

Water Distribution in France. Strasbourg and its Environs. ANON. L'Eau (Fr.) **31**: 124 (Nov. '38). Review of biennial report of city of Strasbourg, '36–'37. System dates from 1878 and has since been enlarged and modernized. In '21 Strasbourg acquired water system of town of Schiltigheim. Through these 2 systems, Strasbourg serves a number of outlying communities, totaling with Strasbourg 269,301 consumers in '37 with daily per capita consumption of 179.5 liters. Bacteriological quality of the tap water is checked by gelatine plate counts 3 times each fortnight, wells themselves semi-monthly, and Schiltigheim reservoir monthly. Tests for *Esch. coli* are made weekly on tap water. Bacteria counts are always slightly high, but of non-pathogenic varieties. Strasbourg supply has total hardness of 256 p.p.m., Schiltigheim 338 p.p.m., mostly bicarbonate. Profits from water sales in '36 were 3,112,995 fr. out of 7,491,172 fr. receipts, in '37 were 2,978,405 fr. out of 7,848,561 fr. receipts.—*Selma Gottlieb.* (See also abstract J. A. W. W. A. **31**: 738 (Apr.'39)).

Successful Completion of a Large Central Water Supply. RUDOLF KRAHL. Gas-u. Wasser. **82**: 66 (Feb. 4, '39). The water supply for Kiel, Germany, (pop. 220,000) has shown defects for several years, namely, high iron content, low supply for peak loads, and increasing pollution of the shallow ground water. Water is obtained from several groups of wells, only two of which are of main importance. One of these caused the iron content in the distribution system because its rapid filter plant was overloaded. Red water was mainly observed by the consumer after a day of low consumption during which iron precipitate deposited in the pipes. Higher consumption caused flushing out of the iron deposits. It was also found that after filter washing more iron

was discharged into the mains. Improved operation and better flow regulation to make the plant load more uniform resulted in reduction in total iron in the distribution system. Raising the level of the bottom outflow pipe in storage basins also helped to eliminate much iron. This was of more importance than the small loss of storage capacity. Increase in yield was obtained by replacing the shallow wells by deeper ones into lower gravel deposits. This also gave relief from increasing pollution observed in the surface wells, a pollution that could not be otherwise eliminated fully.—*Max Suter.*

PUBLIC ADMINISTRATION

Intergovernmental Tax Exemption. A. M. HILLHOUSE. Public Management **31**: 77 (Mar. '39). Conclusions drawn from a study, largely statistical, of the fiscal aspects of legislation before Congress to remove the tax exempt status from federal, state and local securities and salaries. For complete data and reasoning see The Municipal Year Book for '39, published by the International City Managers' Assoc., 1313 E. 60th St., Chicago, 600 pp.; $5.00. The 20 short paragraphs of conclusions are thus summarized: (3) Additional interest paid by states and cities on taxable bonds probably not over 0.25 or 0.5%. (4) Federal gain; states lose, if rise in interest is over 0.125%. (5) Federal gain is good ground for demanding subsidy in exchange for support of constitutional amendment. (7 and 8) Interests of states not homogeneous and of cities not identical with states. Municipalities might well oppose removal of tax exemption until guaranteed participation in resulting increase in state and federal taxes. (11) States and municipalities should oppose all present attempts to reach income from their bonds; but should draft and sponsor carefully drawn constitutional amendment. (12) Neither Lonergan nor Byrd proposed amendments adequately cover state and municipal interests. (14) Salary and tax questions should be divorced. Support might be given to taxation of state and municipal bonds on condition that taxation of public employment income be dropped. (15) Abolish all tax exemption of income from government bonds, thus attaining a socially desirable end and protecting states and cities from discriminatory federal legislation. (19) Sooner or later states and municipalities will have to adopt a positive program. (20) The problem is not of New Deal origin. Given the gradual abolition of the tax-exempt class it seems fairly certain that a way will be found to remove the tax-exempt privilege from state and local bonds.—*M. N. Baker.*

The Awakening to the Loss of Utility Tax Revenues. MARCY B. DARNALL. Pub. Util. Fort **23**: 405 (Mar. 30, '39). Tennessee legislature seriously considering taxing municipal electric systems due to prospective loss of $1,000,000 in yearly taxes of utilities to T. V. A. Legislation sidetracked due to entanglement with proposal legalizing sale of liquor. Most state administration officials predict that tax loss to state and counties as a result of T. V. A. and municipal operations will eventually necessitate a municipal tax levy. Loss of state revenue due to T. V. A. and municipal power systems led to introduction of bill in Alabama Senate taxing municipal power systems.—*Samuel A. Evans.*

Comparative Tax Rates of 294 Cities, 1938. ROSINA MOHAUPT. Nat. Munic. Rev. **28**: 595 (Dec. '38). Tables and brief text. Cities arranged by size down to 30,000. Give assessed valuation; per cent real and personal; breakdown into city, school, county and state; estimated ratio assessed to true value; adjusted rate on 100% basis of assessment; amount of homestead exemption. Av. tax rate for 248 comparable American cities showed a small increase from '37. For 284 cities the range in tax rate for '38 was from $13.35 in Wheeling, W. Va., to $117.38 in St. Petersburg, Fla., actual rates billed. Readjusted, the range was from $9.35 in Wheeling to $56.37 in Atlantic City, N. J. Low rates in Wheeling due to restriction on homesteads at half the full rate and other peculiarities.—*M. N. Baker.*

Minnesota Waterworks Projects Built with WPA Assistance. S. A. SIVERTS, JR. Minnesota Municipalities **24**: 90 (Mar. '39). To detn. potential work available in Minn., survey was made of all municipalities having pop. of 150 or more; of 644 such towns 225 had no water system. Accumulated expenditures of WPA in Minn. to Jan. '39 was $128,121,390 of which 1.89% was for waterworks projects. Towns contributed 22% of total cost of waterworks projects, in one case as much as 72.8%. 199 of Minnesota's total of 746 municipalities affected by WPA waterworks activity; 123.7 mi. of mains laid, 14 new systems built and 114 main extensions and improvements made. Data on 4 projects given in detail, indicates time to do job varied considerably, total federal and sponsor cost per ft. of pipe varied from $2.25 to $4.66 ★[not explained if figure inclusive of material cost]★. Advantages of municipal waterworks include saving on fire insurance, maintenance and operation costs small, and under normal conditions rates less than maintenance of private home plants.—*Martin E. Flentje.*

Home Building—Where, How Many and How Much. ANON. Business Week p. 39, Apr. 1, '39. A tabulation based on permits in all cities of 10,000 or more which is condensed as follows:

REGION	PERCENTAGE INCREASE, 1937 TO 1938	
	Number of Homes	Total Value
New England	−4%	−19%
Middle Atlantic (N. Y., N. J., Penna.)	+59%	+33%
East North Central (Ohio, Ind., Ill., Mich., Wis.)	+1%	−3%
West North Central (Minn., Ia., Mo., N. D., S. D., Neb., Kans.)	+14%	+11%
South Atlantic (Del., Md., D. C., Va., W. Va., N. C., S. C., Ga., Fla.)	+13%	+13%
East South Central (Ky., Tenn., Ala., Miss.)	−0.4%	−2%
West South Central (Ark., La., Okla., Tex.)	+41%	+32%
Mountain (Mont., Ida., Wyo., Colo., N. M., Ariz., Utah, Nev.)	+1%	+0.4%
Pacific (Wash., Ore., Calif.)	+23%	+15%
United States	+28%	+17%

Shall Private Wells and Water Supplies be Allowed Within a Public Water Distribution System? FRIEDRICH KRAUSS. Gas-u. Wasser. **81**: 754 (Oct. 22, '38). The question in the title is considered as having to be answered generally in the negative. Exceptions should only be allowed in cases of large supplies for individual and purely industrial purposes. As reasons for the prohibition of private water supplies where a sanitary supply is available are given: From the standpoint of hygiene it must be admitted that within urban territory soil conditions seldom exist that permanently exclude the possibility of contamination. Private wells are built mainly for economic and not hygienic reasons and their regular supervision is a practical impossibility for health departments. The public water distribution system is always more a part of the public health service for the whole community than a local income producer trying to reduce competition. For this reason double supply systems of drinking and industrial water have mostly been abandoned. From the legal standpoint it is noted that the public supply should not be damaged through the lowering of its groundwater level by private wells. To force connection of every property to the public supply may cause some difficulty, but avoidance of the public supply by private parties damages the general welfare. No groundwater supply is unlimited, and private wells can therefore influence each other or cause damage to structures through settling or rotting of piles. Value of wells as an auxiliary supply to fight fire during aerial attacks is problematical, as the power lines may also be damaged. Underground storage reservoirs of capacities from 75,000 to 135,000 gal. are considered better for this purpose.—*Max Suter.*

The Question of Water Supplies from Private Wells. BERNHARD SCHMIDT. Gas-u. Wasser. **82**: 57 (Jan. 28, '39). Inspired by a previous article (See preceding abstract) data are given by a medical man on the hygienic unreliability of private wells. Investigations showed that more than one-half of the private wells have unsanitary water and that in many cases no improvement is obtained by the health service after complaining for years. Under these conditions no dependence should be placed on private wells as an auxiliary supply during air raids. Specially built wells, furnishing hygienically approved water should be used for this purpose. These wells should be normally sealed and only be made available when needed. Underground storage should be used for fire fighting.—*Max Suter.*

PUBLIC RELATIONS

Congress Eases Up On The Utilities. HAROLD BRAYMAN. Pub. Util. Fort. **23**: 323 (Mar. 16, '39). Public utilities probably have less to fear from the present Congress than they have had from any which has assembled since '30. Punitive legislation, for political purposes, will not be passed, probably some legislation passed will be regarded by public utilities as destructive to their interests. Aggressive anti-utility leaders in House are halved. Defeated Representatives were ardent New Dealers, advocating radical and experimental schemes; people desire a slower approach to Roosevelt objectives. In general, radicals defeated and conservatives won. Senator Norris did not even introduce his bill, supported by the Administration creating so-called "seven sisters of TVA". Oblique instead of frontal attack on public

utilities. "Death sentence" against utility holding companies now being applied. Utility rates now at minimum; attack now changed from against rates, financial organization, and policies to government competition with utilities. New dams advocated at Government expense, in the name of flood control or navigation, then public utility must buy power developed or have government competition. Honest public utilities are required to meet their old political opponents advocating dams developing power, under guise of being for flood control and navigation. Congressmen forced to trade votes, if they desire flood control dams in their own state, however, number of violent opponents of private utilities in 76th Congress comparatively small. Due to popularity of TVA in Tennessee the entire Tenn. delegation is permanently against the utility industry. The peoples' standards of life have been improved and hence Tenn. Congressmen have been forced by the people to support similar projects. Generally speaking the new group of Senators more conservative. The first time in ten years that a majority has not been against the utilities. Senator Norris aging and has not the old spirit, not fostering new projects, Borah and Wheeler also less active. Hiram Johnson turned to foreign affairs; the newer crusaders against utilities not particularly effective. However, while Congress is less unfriendly, President Roosevelt has saved executive appointments for those who he regarded as falling in a good cause. Justice Frankfurter's appointment to Supreme Court cannot add to the confidence of utilities; however, he undoubtedly places justice and law before personal viewpoints. Indications point to President appointing economic radicals to important administrative posts. No immediate unfriendly legislation threatened, Congress more conservative than at any time since '28; prospects appear reasonable that relative political calm will prevail for the utility industry.—*Samuel A. Evans.*

Selling Good Will with Good Water. J. O. Herr. Eng. News-Rec. **122:** 394 (Mar. 16, '39). Systematic public relations program of Monmouth Consol. Water Co. (New Jersey) is discussed. Essentials of public relations program are: (1) careful planning; (2) continuous rather than intermittent application; and (3) spirit of co-operation, good will and friendliness toward customer on part of each employee, together with belief by latter in need for program. Much value has been derived from regular monthly meetings of employees, where general problems are discussed. Topics usually suggested by employees. Film portraying many common errors made in employee contacts with customers and suggesting better methods has been found most useful. Outgrowth of film was establishment of customer relations clinic, at which employees give their versions of how particular questions should be dealt with and then approved methods are presented and discussed. Program includes also invitations to customers to inspect plant, free play showers for children, notification of newspapers regarding new construction and improvements, advertisements dealing with importance and proper use of water, and prompt explanations to customers of reasons for service failures. Adoption of neat, serviceable uniform for meter readers, inspectors and other employees who enter private homes has met with approval of both customers and employees. Every effort made to make each customer, large or small, feel that his patronage is appreciated.—*R. E. Thompson.*

Building Good Will for the Water Dep't. CHARLES L. LINK. W. W. Eng. **92**: 329 (Mar. 15, '39). Mgr. of Elkhart, Ind., gives suggestions for creating good will for municipal water dep't. Employees should keep in mind dep't. judged by product sold and service rendered and that both must be the best. Advises keeping all equipment and plant modern, efficient and attractive. Offers suggestions to employees which include smile a lot, always be courteous, don't argue, never evade a question, make and keep promises, treat customers right, be well informed and sell product.—*Martin E. Flentje.*

A Water-Works Contribution to Health and Happiness. ANON. Am. City. **53**: 8: 45 (Aug. '38). In various communities served by the American Water Works and Electric Co., the water works have provided play showers for children. These are unit fixtures that are readily attached to a hydrant. There are also drinking fountains made of pipe fittings which are attached to fire hydrants.—*Arthur P. Miller.*

The Exhibit Medium. HOMER N. CALVER. Am. J. Pub. Hlth. **29**: 341 (Apr. '39). Exhibit medium offers an effective method of health education. Compared to language, things exhibited may be taken as nouns, color an adjective, motion the verb. Rules governing exhibits not well known. Medium has certain limitations, however it can point out and drive home a few salient facts. Should proceed from known to unknown and ideas expressed should be simple. Audience desired to reach should be kept in mind and purpose of exhibit actually set down and known facts, even if obvious, enumerated. Design should be made keeping in mind selection and arrangement of color, words, lettering, pictures, devices, light. Other elements should be determined by their relationship to the message of the exhibit and their value in achieving its purpose. Ten tried and effective exhibit devices are enumerated. Suggested that exhibit be tried out on test audience before final presentation.—*Martin E. Flentje.*

Municipal Activities in the Movies. JOHN DEVINE. Public Management **31**: 67 (Mar. '39). Practical suggestions by assistant director American Film Center, New York, on subjects, methods and costs for letting citizens know what their government is doing; a way to reach thousands as against scores who see but perhaps do not read municipal reports. Either silent or sound films may be used. A 10-minute reel of sound may be recorded on a 16 mm. film for about $35 and sound projectors for that size of film cost about $250. These may be used for semi-private gatherings in churches, schools or civic clubs. A 35 mm. sound film, one reel, 10 min. service, made professionally, with professional script writer, cameraman and assistant, sound man and the like might cost $3,000 if only a single reel were made at a time. Reels may be adopted for a few minutes showing by regular movies. Action is essential, for "movies must move".—*M. N. Baker.*

Causes of "Milky Water" Troubles Explained and Demonstrated. ANON. W. W. Eng. **92**: 86 (Jan. 18, '39). Comments by W. V. Weir on "milky" water, explanation of which is a water works chore every year. Presence of minute air bubbles in water from house tap due, not only to pressure change but also

to temp. change. Expt. with U-tube given, shows water taken from open tank or res. and pumped into mains will appear at tap as milky water only if tap water temp. is above res. water temp.; and even when warmed bubbles only occur when pressure is released. Explained by Henry's law $m = k\ P$, where m is vol. of gas dissolved at pressure P, and k is constant dependent on temp. and nature of soln. Milky water may be caused by pressure change alone under exceptional circumstances with a pump operating under negative suction head having leaky packing glands or joints through which air can be taken. Warming of water in consumers plumbing probably greatest contributing factor to milky water.—*Martin E. Flentje.*

Knowing How to Profit from the Benefits of Water. VICTOR GERMAIN. L'Eau (Fr.) **31**: 134 (Dec. '38). Although $\frac{2}{3}$ of French communities are still without public water systems, French public opinion is much more alert to question of rural electrification than to water supply. Purification methods used frequently give more apparent security than real. Unfavorable sign, hygienically, is low daily per capita consumption, being less than 50 liters in long established systems, whereas min. recommended by govt. council on hygiene is 100 to 125 liters available. Even with public consumption, only $\frac{1}{3}$ of available volume is used. Causes of low consumption are use of private supplies due to French spirit of economy, lack of sewers, and lack of training in use of water. Propaganda necessary to effectuate change is, for water, in embryonic state, compared with that for gas and electricity. Campaign must be conducted through the press and through demonstrations by water departments, plumbers, etc. Benefits will accrue to the distributor as well as to the user.—*Selma Gottlieb.*

WATER WORKS PERSONNEL

The Effect on Municipalities of Workmen's Compensation. EARL HUTCHINSON. Can. Engr. **76**: 9: 68 (Feb. 28, '39). Workmen's compensation, as it is known to-day, first introduced in Germany in 1885. Operation of the Ontario Act, in effect since '15, is discussed. Administration costs av. about 5%. All costs borne by employers. Rates can be kept down only by reducing no. of accidents. If contractors or sub-contractors fail to pay their assessments, principal is responsible for payment. Since inception of Act, there has been paid in compensation and medical aid nearly 129 million dollars. In '38, there were 59,834 claims and $6,464,261.19 was paid out. Approx. 97% of all claims disposed of without difficulty. Claims and assessments handled in routine manner by respective depts. and when disputes arise they are referred to the Board.—*R. E. Thompson.*

Public Employee Retirement in the United States. ISRAEL RAFKIND. Munic. Finance **11**: 10 (Feb. '39). Due to the federal social security program, retirement pay for public employees is receiving renewed interest. In 1834 civil service pensions had their modern start in England. In 1857 the first public employee retirement system in this country was applied to New York City policemen. At the beginning of '38, data gathered by International City

Managers' Assoc. showed 545 retirement systems in 819 reporting cities of over 10,000 pop. Most cities confine the plan to police and firemen. Public school teachers in 29 states, Dist. of Col., Canal Zone, Hawaii and Puerto Rico are covered by state-wide systems. In other states, teachers in 26 cities are covered locally. Over 500,000 employees in federal service are included under federal retirement acts and state employees in Me., Mass., R. I., Conn., N. Y., N. J., Penn., Md., Va. (in part), Colo. and Calif. benefit by state retirement systems. Several states contemplate adopting the system. There is a trend toward sound actuarial systems but in '36 of 545 retirement systems 36% were on an unsound basis. Some persons look to federal and to state-wide or individual old-age insurance as the answer to the public employee retirement problem. The federal act is a *social* not a *personnel* program. As such it is a subsistence program designed to give the greatest possible benefit to the lowest income group. The federal program includes neither a compulsory nor flexible retirement age, both essential if the employing government is to get the greatest value. Complete coverage of public employees and immediate vestment of employer contributions are desirable to promote public service as a career. To accomplish the latter employees must be able to transfer freely from private to public and from public to private employment without loss of accrued benefits. This transfer will be facilitated only by complete vestment of all credits under both individual and state-wide public employment retirement plans, even if the latter supplement coverage under the federal program. —*M. N. Baker.*

How to Develop a Sound Retirement System. ISRAEL RAFKIND. Public Management **21**: 41 (Feb. '39). An adequate retirement plan for municipal employees promotes social security and devotion to a career for the employee and also to the interests of the public. Of the many plans in use or proposed no one plan is ideal and none is suitable for general adoption. To formulate a plan for any governmental area requires careful study to meet local needs and legal requirements. The task should be assigned to a committee representing employees, administrative officials and taxpayers. Adequate funds for technical advice and incidental expenses should be provided. Committee members should familiarize themselves with the literature of the subject, including reports of commissions elsewhere. Adequate legal advice is essential. This may be given by the municipal attorney. Assistance of an experienced actuary is imperative. He should inform the committee on needed data for computing probable costs of various benefits, and should prepare service mortality and salary tables from which the cost of any proposed retirement system may be calculated. No provision should be adopted until the cost is known. First consideration should be given to future employees; then to provision for present employees, some of whom may have reached the retirement stage for which adequate provision may be lacking. If a retirement plan is in use, the actuary should analyze as to financial soundness and possible needed revisions to ensure funds to pay promised benefits. Small cities face the most difficulties in framing a retirement plan since their number of employees may be too small to make the law of averages applicable. The states of New York and New Jersey allow cities to participate in their state employees retirement

fund; in Ohio this is compulsory for all county and municipal employees not covered by an individual retirement system prior to July 1, '38. Illinois municipal utility employees may participate in a state retirement fund. State-wide plans are contemplated in Pennsylvania, Virginia, North Carolina, Michigan, Iowa and California. The insolvent condition of many retirement funds emphasizes the need for financial soundness. A system that does not include a compulsory retirement age will not accomplish the objectives of either employers or employees since aged employees will remain in the service. One retirement age will not meet all classes of employees nor all employees in one class. Policemen and firemen pass reasonable efficiency sooner than clerical employees. Employees who cannot readily be replaced or who have unusual ability may well be retained on recommendation of their departmental head and approval of the personnel office. To encourage persons of character and ability to seek public service as a career public employment must be made more attractive. Private employees have old-age insurance and other benefits and can transfer from one industry to another without loss of federal benefits. Public employees should be able to transfer likewise between units of government. Another inducement to public career service is retirement dependent on age rather than years of service. When a person separates from the service his accumulated credits should be retained as a deferred annuity to begin at some minimum retirement age. A retirement system may be viewed as a compulsory provision for old age. Years ago retirement benefits were viewed as rewards for faithful service. Today they are considered a social necessity and desirable to round out personnel policy.—*M. N. Baker.*

Merit System Stages Successful Comeback in Connecticut. PATERSON H. FRENCH. Nat. Munic. Rev. **28**: 192 (Mar. '39). Connecticut enacted a merit system for state employees in '13, emasculated it by successive amendments and repealed it in '21. In '37 a new law was enacted. Up to mid-Oct., '38, 127 examinations had been given 20,347 applications received, 13,735 persons examined, 6,039 placed on employment lists and 1,093 appointed. Of 11,756 persons in state service Oct. 31, '38, 10,264 were in the classified service. The personnel director is appointed by the governor with Senate consent at $7,500 a year, for an unlimited term, removable by governor for "misconduct, incompetency or neglect of duty". The governor chooses him from "eligible persons" selected by an advisory personnel committee of ten picked by the governor from state department heads. This committee advises the personnel director in formulating rules and regulations and in establishing and maintaining procedure and technic. Existing employees taken into the merit system without examination. Examinations for new employees cover "qualifications, fitness and ability". There are no formal educational requirements but education may count as an alternative for experience. Two years residence in Conn. required except where "no qualified resident of the state shall apply". Veteran preference is given, with 10% "eligible for disability compensation" and 5% for all others, providing examination is passed. Qualifications for various positions are determined by consultation with department heads. Unpaid examining committees of citizens are recruited largely from outside the state service. ★[With modifications, the Conn. state system could be

applied to city employees, either under state or local control; in fact, it is in many respects similar to existing city systems. In at least one state (New Jersey) cities may elect to come under the state civil service system.]★—*M. N. Baker.*

One in Every Nine Works for the Government: A Review of Public Payrolls. EDWARD R. GRAY AND WILLIAM R. DIVINE. Nat. Munic. Rev. **28**: 204 (Mar. '39). Even excluding those on relief 1 of 9 employed persons in the U. S. was in federal, state, city or other public employment in '37. See accompanying tables which are discussed at length by the author. In '36 about 9% of all full-time municipal employees in cities above 100,000 pop. were in such public service enterprises as municipally operated water works, electric light plants, street railways and airports. Part-time employees are probably over 6% of total employees in cities of over 10,000 inhabitants and about 5% in cities of over 100,000.—*M. N. Baker.*

1. GOVERNMENT EMPLOYEES[a] IN THE U. S., '29, '33, AND '37

Source: U. S. Bur. of For. and Dom. Commerce, *Income in the U. S., 1929–37*, Washington, Nov. '38, p. 36. (Original table has similar data for each year '29–'37 incl.)

	NUMBER OF EMPLOYEES (000's OMITTED)			PERCENTAGE OF 1929		
	1929	1933	1937	1929	1933	1937
Total employees in U. S.	34,863	25,973	32,546	100.0	74.5	93.4
Total private employees	31,659	22,754	28,782	100.0	71.9	90.9
Total government employees	3,204	3,219	3,764	100.0	100.5	117.5
Federal	862	856	1,202	100.0	99.3	139.4
State	264	306	367	100.0	115.9	139.0
City	718	640	697	100.0	89.1	97.1
County, township and minor units	269	260	298	100.0	96.7	110.8
Public education	1,091	1,157	1,200	100.0	106.0	110.0

[a] Part-time employees included at full-time equivalent. Work relief employees excluded.

2. TOTAL AND AVERAGE SALARIES AND WAGES OF GOVERNMENT EMPLOYEES IN THE U. S. '29, '33 AND '37

Source: U. S. Bur. of For. & Dom. Commerce, *Income in the U. S., 1929–37*, pp. 37–8.

	TOTAL SALARIES AND WAGES (IN MILLIONS OF DOLLARS)			AVERAGE COMPENSATION PER EMPLOYEE		
	1929	1933	1937	1929	1933	1937
Total all employment (government and non-government)	$50,572	$27,963	$42,828	$1,451	$1,077	$1,316
Total government	4,794	4,323	5,410	1,496	1,343	1,437
Federal	1,398	1,221	1,918	1,622	1,427	1,595
State	342	373	469	1,296	1,220	1,278
City	1,167	934	1,102	1,625	1,459	1,581
County, township, and minor units	376	331	396	1,397	1,275	1,326
Public education	1,511	1,464	1,525	1,386	1,265	1,272

3. Number of Employees[a] and Av. Salary Per Municipal Employee on Dec. 31, '36, in 781 Reporting Cities Having a Population of Over 100,000

Source: International City Managers' Association, Municipal Yearbook, 1937, p. 267.

Population-size of city	Number of cities reporting	Number of employees (in thousands)	Payroll (in millions of dollars)	Average salary per employee (in dollars)
All cities reporting	781	497.0	877.0	1,765
Over 500,000	11	239.8	511.4	2,132
200,000 to 500,000	23	75.5	107.5	1,425
100,000 to 200,000	48	52.8	83.3	1,578
30,000 to 100,000	186	73.7	107.3	1,457
10,000 to 30,000	513	55.2	67.4	1,222

[a] Part-time employees included at full-time equivalent. School employees excluded as well as one or more other specific departments in many of the cities reporting.

4. Number and Percentage Distribution of Full-Time Municipal Employees, April 1, 1936, in 94 Cities Having a Population Over 100,000

Compiled from data published in U. S. Bur. of Census *Financial Statistics of Cities Having a Population of Over 100,000, 1936*, Washington, 1938. P. 207 ff.

(Number of Employees in Thousands)

	Municipal employees by size of city							
	All cities over 100,000		Cities over 500,000		Cities between 300,000 and 500,000		Cities between 100,000 and 300,000	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
All departments including public service enterprises	689		436		89		164	
Regular departments[a]	631	100.0	397	100.0	81	100.0	152	100.0
General government	46	7.2	32	8.0	7	8.0	7	4.9
Protection to person and property	132	20.9	85	21.5	15	18.8	31	20.7
Police department	76	12.1	54	13.5	8	9.5	15	9.9
Fire department	47	7.5	26	6.4	6	7.8	15	10.0
Other	9	1.4	6	1.5	1	1.5	1	0.8
Conservation of health	21	3.4	14	3.5	4	4.5	4	2.5
Sanitation	58	9.2	41	10.3	6	7.3	11	7.3
Highways	28	4.5	16	4.0	5	5.7	8	5.0
Charities[b]	13	2.1	9	2.2	2	2.7	2	1.6
Hospitals	35	5.6	26	6.6	6	7.0	3	2.3
Corrections	6	1.0	5	1.2	1	1.2	[d]	0.3
Schools[c]	252	39.9	144	36.3	32	39.6	75	49.6
Libraries	12	2.0	8	1.9	2	2.0	3	1.9
Recreation	24	3.7	16	4.0	2	2.9	5	3.5
Miscellaneous	3	0.5	2	0.6	[d]	0.3	1	0.5
Public service enterprises	58		39		7		12	

[a] Excluding employees of public service enterprises, which are shown separately following the regular departments.
[b] Including supervision of charities, hospitals, and correction.
[c] School employees for the full school year were reported as for full time.
[d] Less than 1,000.